JOURNAL

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OF THE INSTITUTION OF ELECTRICAL ENGINEERS

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FUSION NOT FISSION

IT IS THE FASHION TO-DAY FOR PUBLIC SPEAKERS—BOTH informed and uninformed—to allege that Britain is slow in the picking of technological fruits from the seeds of scientific research. Whatever the truth of such criticism in certain industrial processes, there can surely be only praise for the way in which work in Britain on nuclear energy and radioactive isotopes for peaceful uses has progressed. In August, 1945, with the mingled shock and relief of Hiroshima still swamping thought of the future, few engineers would have dared to suggest that the first British nuclear power station (at Calder Hall in Cumberland) would be nearly completed in ten years' time, and that others would be following on its heels to mitigate an ever more alarming shortfall of coal; here is one of those all-too-rare peace-time endeavours in which scientific development has thrust ahead faster than its sponsors originally expected. Impressive too is the ever-growing use of radioactive elements and compounds in industry, medicine and other activities, which is mirrored in the recent formation of the Atomic Energy Authority's Technological Irradiation Group and in the long catalogue of products available from the Radiochemical Centre at Amersham. All praise to the Governments who have given a lead in this work and to the engineers and scientists who have carried it out.

The wealth of design and constructional work involved in the equipment of the atomic research establishments and factories both for military and peaceful uses has given rise to the concept of "nuclear engineering," and indeed of "nuclear engineers," though these are at present—and may always be in Britain—disguised physicists, metallurgists, or engineers of longer-established kinds. The principal aims of nuclear engineering are at present the generation of energy, the supply of radioactive isotopes, and the production of atomic explosives, but the third aim is still so shrouded in security regulations that we question whether it is useful to discuss it as part of the nuclear engineer's job; its practitioners are unhappily unable to submit their techniques to full professional discussion.

Clear though the aims of nuclear engineering may be, its technical compass is not easy to define. At the first approach, its frontiers appear to lie along those of basic sciences and technologies such as physics, chemistry, metallurgy, and civil, mechanical, electrical and chemical engineering. The subject savours, in fact, of one of those irritating counties in the Midlands that impinge on more than a reasonable share of their colleagues—counties that are the delight of quiz composers and, presumably, the bane of cartographers, who must be grateful to the mathematicians for the reassurance of the—unproved—four-colour theorem. But on reflection one realizes that nuclear engineering is, on the previous analogy, more akin to the country transport system of a large town. Without possessing technical territory in its own right, it has many arteries of communication that find their way across the territory of neighbouring technologies. Whether the hub of the system should be the county town of Atomic Physics or of Chemical Engineering is debatable. The cardinal point is that nuclear engineering is not a primary technology; indeed it is unlikely that it will ever be considered one, for the studies involved—nuclear fission, heat transfer, fluid flow, gaseous diffusion, materials of construction, radiation measurements, etc.—are all catered for in the basic sciences and five primary technologies.

Having in mind this theme—that nuclear engineering consists of, rather than abuts upon, the basic sciences and technologies—The Institution, with The Institutions of Civil, of Mechanical and of Chemical Engineers, and The Institute of Physics, has jointly set up the British Nuclear Energy Conference, the aims of which were outlined in the June *Journal*, page 339. This is an eminently sensible and practical step and a striking indication of the co-operation that exists between the major scientific societies to-day. There is, as indeed all

engineers know, a plethora of professional and pseudo-professional engineering bodies in Britain—though fortunately The Institution's system of Specialized Sections has forestalled all serious "splinter groups" within the engineering domain it influences. Nuclear engineering is clearly a subject for which a new *professional* organization is not required; scientists and engineers of many different disciplines will practise it, and their prime need is for a common meeting ground for discussion, and at least one medium for publication of technical information. These the British Nuclear Energy Conference will supply. Later its activities may broaden a little. The United Kingdom Atomic Energy Authority already has a statutory duty over technical training, and with the spread of nuclear power development into private industrial hands, the B.N.E.C. may have a role to play in the field of post-graduate training, but it is likely to be that of a forum in which training policy can be discussed rather than an advisory body in its own right. The existence of the B.N.E.C. does not, of course, imply that independent professional qualifications in nuclear engineering should be established.

The B.N.E.C. fully appreciates the need for the international exchange of information in its field; it will arrange British participation in international conferences such as the great U.N. Conference on Peaceful Uses of Atomic Energy held in Geneva this month, and it will itself promote national and international conferences.

Perhaps the weakest facet of the new organization is its title—the President in introducing the Annual Report of The Institution on May 19th described it as it is known "for want of a better name." Really a "consortium," it has wisely rejected this confusing word from its birth certificate, but although there are precedents for using the word "conference" in a permanent sense, to many it is suggestive of a body which meets at most, say, twice a year. However, "let be my name until I make my name"; present choice does not preclude future change, as The Institution's own history exemplifies.

The Conference is leading off in November of this year with a symposium of lectures by some of the outstanding scientists and engineers engaged in its field. We wish it much success in this its first activity, and in its "Forthcoming Events." The Conference will be a most rewarding endeavour—rewarding to the prestige and advancement of British industry, and to the scientists and engineers who attend its meetings and read its publications. The mingling of ideas from men of different outlook will, as in all learned societies, prove invaluable. Sir John Cockcroft—one of the distinguished members of the Conference's Board—has recently described the Dounreay reactor as "a physicist's dream but an engineer's nightmare." Members of The Institution may feel confident that nuclear dreams and nightmares will be successfully analysed and reconciled under the aegis of the B.N.E.C.

A Film for Boys

THE Institution's new film, *The Inquiring Mind*, to which members will have seen references in the July issue of the *Journal*, will very shortly be holding the attention of some of the young audiences for whom it is intended. Its declared aim is to show the opportunities of an electrical engineering career to those who have not yet decided upon their future, and by that means to foster inspiration in boys of the calibre the profession needs, not merely for assuring the future of the electrical industries but indeed for the nation's economic survival.

The Inquiring Mind is particularly addressed to boys in the upper forms of public and grammar schools who have not yet thought deeply about the possibilities of an engineering career. It includes, near its beginning, brief glimpses of the education and training of a boy who moves from the classical side at school to take up a career in electrical engineering. This is followed by a brilliantly photographed panorama of many aspects of electrical engineering, and the film ends in the Lecture Theatre of The Institution on an inspiring note that is emphasized by some well-known words of Michael Faraday.

The film received a good reception by the Press and by those at its première, and the Council have reason to be optimistic that it will in due course make a real contribution towards increasing the number of entrants to the profession. Some 12 applications for loan of the film, which runs for 30 minutes, have already been received from schools and other organizations. The film was televised by the B.B.C. on August 5th, and it will also be shown during the Radio Show at Earl's Court this month.

The production of the film was made possible by the unsparing co-operation over nine months which the film company, Verity Films, and The Institution received from numerous electrical organizations, including, particularly, many firms in the electrical industry; these have contributed generously to the cost of the film, not only by grants of money but also by allowing shots to be made in their premises or by making available suitable existing private films from which extracts have been taken. The Institution, Mr. O. Skilbeck (the producer) and Mr. S. Head (the director) gratefully acknowledge the help of all concerned.

CANADA'S FIRST SUBWAY CARS

When Toronto became the first city in Canada to inaugurate a public subway for passenger transport, its engineers had a wealth of experience in Europe and the United States to study. While it is natural to expect that they would have inclined strongly towards the views of their neighbours, the Toronto Transit Commission selected from all over the world the ideas best suited to their local conditions and finally had their rolling stock built in England.

FRANK W. ROBERTS, B.Sc.(Eng.), M.E.I.C.,
Associate Member

ON the 30th March, 1954, the last streetcar-plus-trailer system on the North American continent gave way to Canada's first subway in the short space of 75 minutes. The first train was carrying revenue passengers at 1.30 p.m., and the last streetcar southbound on Yonge Street left its Eglinton terminal at 1.00 p.m., being finally withdrawn from service at approximately 2.15 p.m. This remarkable achievement was accomplished completely successfully and the homeward-bound rush-hour passengers, brought to work by streetcar, travelled home in the evening by underground without any confusion.

The new subway cars, completely designed and built in Great Britain, are fully described in an Institution paper* soon to be republished in the *Proceedings*, which also gives details of their electrical equipment and a general description of the city with its traffic problems.

The City of Toronto

The need for the subway arose in the usual manner; the growth of the city of Toronto into a metropolitan area with a population of more than a million had congested the downtown streets sufficiently to reduce the average speed in the rush hour to about 6 m.p.h. as far back as 1946. Additional streetcars would have added to the congestion rather than relieved it, and the logical solution was a rapid-transit system on a private right of way; a subway was the most economical compromise. The transport system of the Toronto Transit Commission (T.T.C.) originally was confined within the city limits until January, 1954, and was subsequently

* ROBERTS, FRANK W.: "The Electrical Equipment of the Toronto Subway Cars," *Proceedings I.E.E.*, Paper No. 1754, October 1954 (102 A).

1 *Map of route*

Rapid-transit subway.
Surface-car subway.
Surface-car routes using subway.

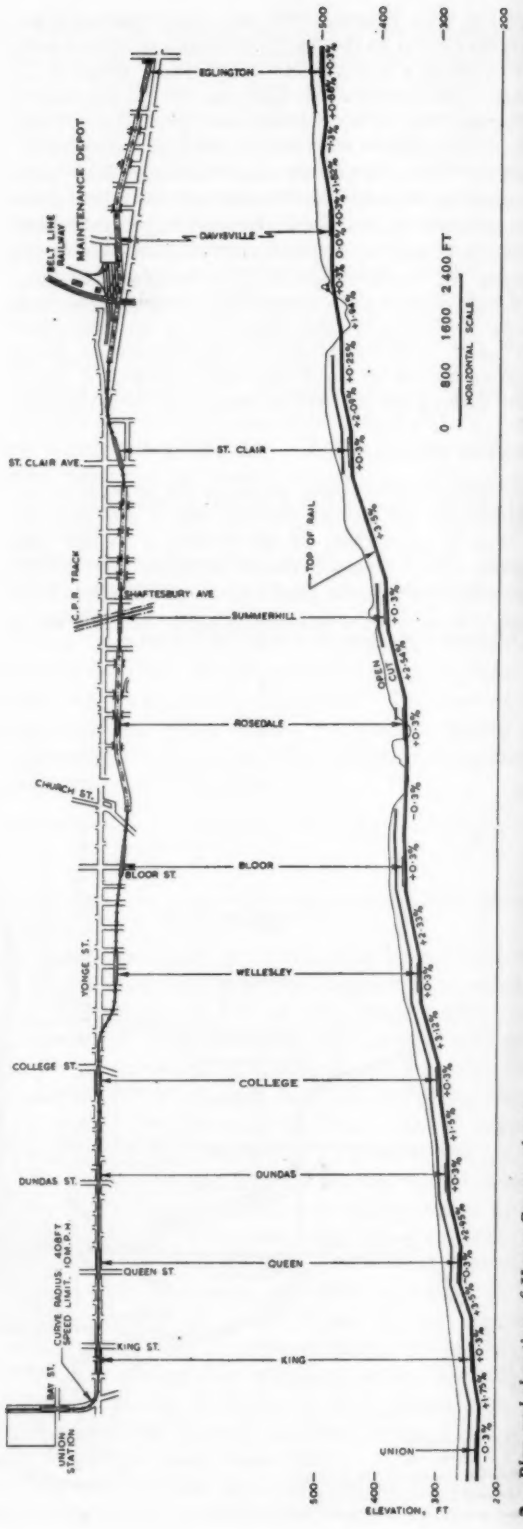
extended by the absorption of several smaller suburban systems to embrace the whole of the metropolitan area. Within the city, the T.T.C. operates by means of a single flat-rate fare structure, irrespective of distance, and with unlimited free-transfer facilities. Additional fares are levied and corresponding transfer arrangements are made in the suburban zones outside the city. This concept of a transport system early led to a gridded type of service with many routes running in the centres of streets approximately parallel in an east–west direction, with similar north–south arrangements (Fig. 1). Hence it fitted local habits to divert passengers onto the new north–south subway by providing extensive and easy transfer facilities to and from 26 east–west routes and, at the same time, to eliminate some north–south surface routes near the new construction. The extension in July, 1954, to outer zones with a new fare structure did not affect this, since the zonal areas lie outside the city and are remote from the subway.

With such a fare structure it is essential that the transfers between subway and surface routes shall be quick and easy, and that is one of the major reasons why a shallow cut-and-cover construction was adopted rather than a deep tube type of tunnel. The correctness of that decision is evidenced by the heavy loading on the subway from the start, and, as has always happened following electrification, the actual increase in number of passengers carried has been greater than the initial official estimate. In 1954 25 000 persons were carried per hour in the peak periods and the daily total on working days was approximately 200 000 passengers. Signalling permits the movement of some 30 trains per hour on green lights or approximately 40 trains per hour on yellow; if 8-car trains are operated, a maximum rate of about 40 000 passengers per hour is possible.

The Yonge Street subway (Fig. 2) is 4½ miles long, with a steady gradient rising from the southern terminal of Union Station through 265 ft to the present northern terminal at Eglinton; the average gradient is approximately 1 in 90 and the maximum gradient is approximately 1 in 30, but these do not present great difficulties to modern multiple-unit electric stock, particularly since the track is almost straight and has only one severe curve through 90° (with a radius of approximately 408 ft) at the southern end. Approximately two-thirds of the system is underground in a box-shaped reinforced concrete structure with an internal overall width of 32 ft 6 in except at stations; terminal-station platforms are islands 24 ft wide, but at intermediate stations side platforms 12 ft wide are used, both types being 500 ft long. At present, seven of the twelve stations are equipped with a total of 15 escalators, and provision has been made for more if needed.

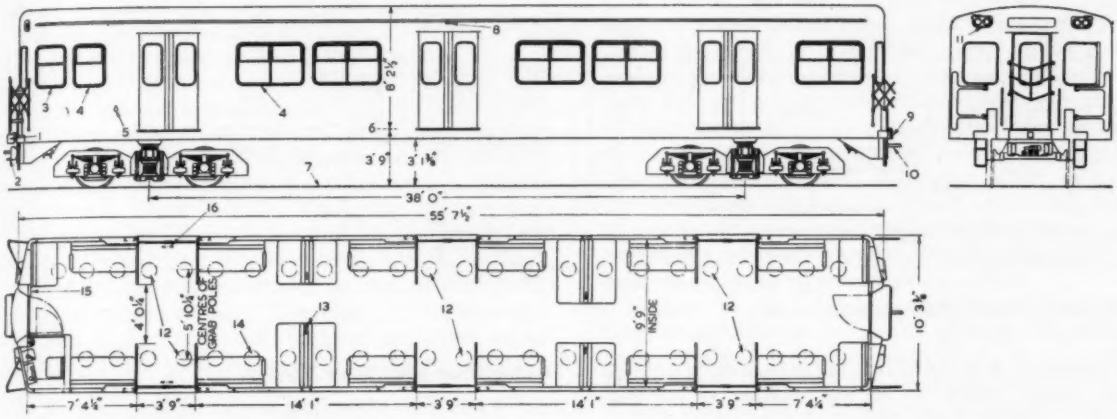
The Cars

The trains are supplied at a nominal voltage of 600 volts d.c. with the well-known third-rail system of collection; the power supply is derived from mercury-arc rectifier substations fed by distribution mains at 13·2 kV



2 *Plan and elevation of Yonge Street subway*

and 60 c/s; rectifiers are rated at 1½ MW, but are grouped to give total outputs of 2½ or 5 MW and connected to give the effect of 12-phase operation. The rolling stock (Fig. 3) shows some similarity externally to the latest R stock of the London Transport Executive (L.T.E.) and the cars are 55 ft 7½ in long over anti-climbers, with an internal width of 9 ft 9 in. Steel cars have an average tare weight of 83 470 lb. while four trial aluminum-body



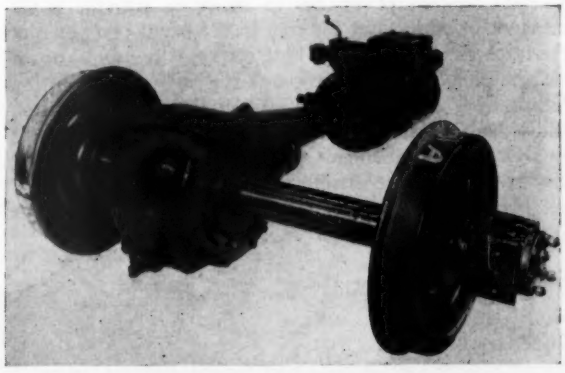
3 *Plan and elevations of subway car*

1. Spring bumper.
2. Automatic coupler.
3. Full-drop window.
4. Half-drop window.
5. Key-operated staff switch.
6. Floor level.
7. Rail level.
8. Door indicator light.
9. Dead bumper.
10. Bar coupler.
11. Marker lights.
12. Emergency lights.
13. Grab handle.
14. Light fittings.
15. Fire extinguisher.
16. Emergency door operator.

cars average 73 440 lb each. The cars have three door openings per side, each with the well-known system of two independently air-operated doors per opening. Driving cabs are small, occupying approximately one-third of the width of the car, and are provided only at one end of each vehicle. Cars are of two types, one containing a motor-generator set and battery and the other containing the air compressor, but are otherwise identical; as a result, a 2-car unit is semi-permanently coupled and is the smallest that can be operated. Fully automatic couplers are used to unite 2-car sets to form trains of up to eight cars.

The average distance between stations is 2 145 ft and the overall run is approximately 4½ miles; hence a round-trip schedule speed of 14½ m.p.h. including a 3-min layover at each terminus is brisk, but it has been possible recently to increase this speed somewhat, partly as a result of shortening the layovers and partly because of decreasing station stop times. The average speed southbound, i.e. downhill, is approximately 17½ m.p.h. including station stops but excluding layovers; the corresponding northbound figure is 17 m.p.h. The calculated balancing speed of a loaded train on straight and level track is 46½ m.p.h., but this speed is not attained, for there is only 650 ft of track without gradients and the free-running time is normally brief owing to the proximity of stations. Accelerating current can be varied with passenger loading over the range 280–320 amp per motor; for an 8-car train with the motors grouped in parallel this would give a mean current of 4 800 amp, but at present trains do not exceed six cars.

The traction motors have a 1-hour rating of 272 h.p. per car, every axle being driven. The transmission of power is not through spur gearing, as the motors are frame-mounted with provision made for relative movement between them and the axles, each of which carries

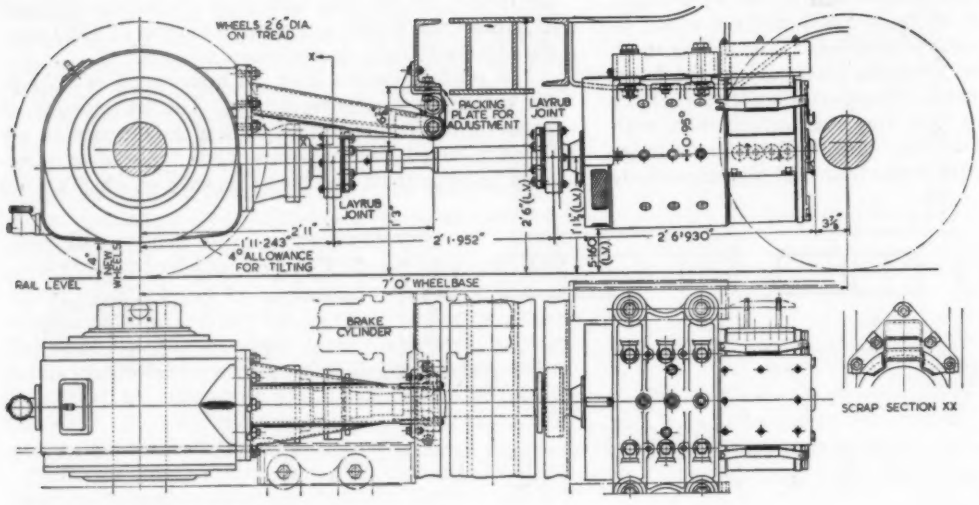


4 *Typical motor coupled to gearbox and axle*

a right-angle-drive gearbox. Fig. 4 shows a typical motor coupled through a flexible cardan shaft to a gearbox mounted on an axle, while Fig. 5 details the transmission arrangement. The well-proved electro-pneumatically operated camshaft type of control gear has been fitted to these cars with great success, and this, together with the series-parallel switch, has been described previously.* Each car has been equipped with a 30 kW heating system for use during the winter and a ventilating system for use

* Hippisley, E. T., and Butler, F. E.: "Control Gear and Auxiliary Machines for D.C. Multiple-Unit Electric Trains," *Proceedings I.E.E.*, Paper No. 966, March 1950 (97, Part 1A, p. 234).

2 *Plan and elevation of Yonge Street subway*



5 *Plan and elevation of the transmission unit*

in the summer. A motor-driven fan in each car circulates approximately 2000 ft³ of air per minute; in summer fresh air is drawn from outside, but in winter either fresh or recirculated air is heated by passage over three 10 kW heaters directly energized from the 600-volt track supply. The lighting within the cars is generous, the majority of the lamps being energized from the track supply; however, six of the 41 lamps are supplied by the 50-volt low-voltage system in order to provide some measure of emergency lighting in the event of failure of the track supply. The braking system is the well-known electric-pneumatic self-lapping system* incorporating retardation control by means two mercury tubes. Individual brake cylinders have been fitted to the cars, each actuating a single shoe; since clasp brakes are employed, there are therefore 16 brake cylinders per car, each having an adjustable fulcrum to enable the leverage ratio to be altered over a wide range.

* BROADBENT, H. R.: "Electro-Pneumatic Brakes," *Proceedings I.E.E.*, Paper No. 905, March 1950 (97, Part 1A, p. 250).

Comparison with Other Systems

The new Toronto rolling stock may be compared with other modern city stock, such as the Waterloo and City trains installed in 1940, the deep-level tube stock on the Bakerloo and Northern Lines and the latest surface stock of the L.T.E. Across the Atlantic the 1952 extension in Boston and the new cars in New York are the most recent. All these operate at approximately the same voltage, i.e. nominally 600–660 volts d.c., and employ conductor rails to feed the trains, although for local reasons Boston has used overhead catenary construction for its eastern extension. Data from these systems are set out in the following Table, using, wherever possible, 8-car trains as a common denominator.

When the systems are compared, the Canadian cars are seen to follow British trends in respect of weight and power ratios, whereas the Boston system has closely followed the Presidents' Conference Committee (P.C.C.) streetcar designs, as being lighter in weight and intended for short-haul frequent-stop service. The R 10 stock in

Comparison of Systems

System	Number of cars per train	Seats	Tare	Installed h.p.		Weight/power ratio		Initial acceleration	Average run
				1-hour rating	Continuous rating	1-hour rating	Continuous rating		
			lb			lb/h.p.	lb/h.p.	m.p.h./sec	ft
Toronto Subway	8	496	667 760	2 176	1 792	306	372	2·3	2 145
New York (R 10)	8	448	648 000	3 200	2 640	203	246	2·5	3 874
New York (R 12)	8	352	608 000	3 200	2 640	190	230	2·5	2 561
Boston (East Extension)	8	384	379 200	1 760	1 520	216	250	2·3	2 864
L.T.E. aluminum Surface stock ..	8	320	515 000	1 760	1 280	293	402	2·0	3 400
L.T.E. steel Surface stock	8	320	609 000	1 760	1 280	346	476	2·0	3 400
L.T.E. Tube stock	7	290	396 000	1 680	1 200	236	310	1·45	3 700
Waterloo and City Line	5	236	253 120	760	—	300	—	1·10	7 413
Paris articulated	9	255	357 148	1 104	936	323	381	2·18	1 709
Paris rubber-tyred	7	336	273 375	1 488	1 184	183	230	2·19	1 709

New York has dimensions somewhat similar to those of the Toronto cars but is used on an express schedule, whereas the R 12 stock, which operates a local stopping service, is narrower and shorter; however, both types have a cab at each end and all axles motored. The R stock on the surface lines of the L.T.E. has dimensions nearer to those of the R 12 stock in New York than to those in Toronto, but has a single driving cab and only half its axles powered, using axle-hung motors.

The articulated trains on the Paris Metro are made from 3-car sets carried on four 2-axle trucks; each set is 120 ft long, 8 ft wide and 11 ft 4¼ in high from rail to roof. Although shown as nine cars in the Table for comparison, these trains usually total only three or six cars, thus including four or eight motors respectively. The rubber-tyred trains are not articulated and are usually operated as 5-car sets, 249 ft long, but sometimes as 4-car sets, 198 ft long; each set comprises three motored cars with two or one non-motored trailers respectively. The 7-car set tabulated for comparison would have four motored and three unmotored cars. These cars are 8 ft wide and 11 ft 5½ in high, rail to roof; motored cars drive on all four axles. Paris proposes soon to raise its present track supply from 650 to 750 volts.

The Table suggests that the weight/power ratios are increasing in recently built equipments; this may be due to better utilization of the traction motors, with a corresponding reduction in installed horsepower for a given duty. Accelerations seem to be stabilizing at 2–2·3 m.p.h./sec for vehicles operating on enclosed tracks and stopping 1½–2 times per mile. This rate was chosen for Toronto under the influence of the view that higher rates are not economically justified, although adhesion would permit them in both Toronto and Boston.

As a comparison of auxiliaries, the trains running in Great Britain have low-voltage lighting, no pressure ventilation and only a small amount of internal heating, but those in the United States and Canada use series circuits supplied at 600 volts for lighting and incorporate both ventilating and heating apparatus. The differences in heating are largely due to climatic variations.

Looking to the future, we can be sure that the new subway has successfully achieved all that it was expected to do and has set a pattern for future development in Ontario. Recent operational data from Toronto may be of interest. In January, 1955, 3 500 000 persons passed through the turnstiles, and about the same number transferred from surface routes; some 29 000 were carried in the maximum peak hour almost entirely in one direction; for the same month, 490 300 car-miles were operated, with sixteen 6-car trains in peak hours at a 2¼ min headway, i.e. 36 min per round trip of 9 miles. Serious consideration is being given to new lines in the same city and also to the ultimate extension northward of the present route. As is so often the case, the magnitude of the financial investment involved is a deterrent, but the sharp increase in real-estate values which has followed the substitution of streetcar tracks by a subway on a separate right of way has shown that there are cash, as well as intangible, benefits to the city from the investment of money in improved transportation.

Because of the great inconvenience of the cut-and-cover construction in Toronto in 1949–54, tunnelling has been suggested for future extensions. It is therefore interesting to note that the Parisians found pillar-and-gallery mining methods practical in their dry subsoil, although some shield tunnelling was used, for example under the River Seine; cut-and-cover methods were used only for a few sections where the water table was near ground level. The avoidance of disturbance to the general public and to street transportation was a great advantage.

Acknowledgments

The author is indebted to Bepco Canada Limited for the facilities needed to prepare this article, and to the Toronto Transit Commission for freely providing data. His thanks are due to the car builders, the Gloucester Railway Carriage and Wagon Co., for permission to publish details of the cars, and to the Régie Autonome des Transport Parisiens, and particularly M. Ruhlmann, for the data on its system.

A typical 6-car train northbound out of Bloor Street Station

Journal I.E.E., August 1955

An Electrical Engineering Review

TELEVISION PICK-UP TUBES

Part II. Design, Operation and Characteristics

In this, the second part of Professor McGee's review, he describes the essential features of five well-known pick-up tubes. Each of these represents a small group of tubes, and illustrates a stage in development, although every tube described is still in use to-day. The first part of the review appeared in the July issue, page 404.

Professor **J. D. McGEE, O.B.E., M.Sc., Ph.D.,**
Associate Member

1 Introduction

THE physical principles employed in television pick-up tubes have already been outlined in Part I. They may be summarized as follows:

(i) The conversion of light to electricity, which may be accomplished by either the photo-emissive, the photoconductive or the photovoltaic effect.
(ii) The integration of the electric charges on photosensitive mosaics, on non-photosensitive mosaics (by the use of an image section), or on a photoconductive layer.
(iii) The discharge of the mosaic elements by scanning with an electron beam, which restores the positively charged elements to anode potential, cathode potential or second cross-over potential.

These principles have been embodied in many different ways in the designs of complete pick-up tubes, but tubes of only five types have had extensive use and the description which follows will therefore be confined to them.

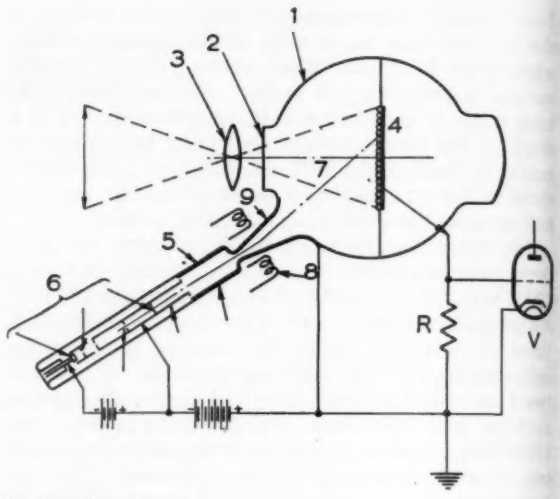
Most of these five types include tubes of more than one trade name, and while the main features may be common to all of one type it should be noted that the description given here refers specifically to the first named in each group.

(*a*) Emitron; iconoscope.
(*b*) Super-Emitron; image iconoscope; super-iconoscope; Photicon.
(*c*) C.P.S. Emitron; orthicon.
(*d*) Image orthicon.
(*e*) Vidicon; Staticon.

2 The Emitron

Although this tube must be regarded as obsolescent, it is actually still in use—over 18 years after it was used by the B.B.C. to initiate the world's first high-definition television service in 1936.

The tube is shown diagrammatically in Fig. 1. Briefly,



1 *The Emitron*

the target is of the type described in Part I [Section 3, Fig. 3(*a*)]. The optical image, formed by the lens 3, and the high-velocity scanning beam 7 projected by the electron gun 6, both fall on the same photosensitive mosaic surface of the target 4. The light liberates photo-electrons, and the scanning beam liberates a large number of secondary electrons, some of which reach the anode 9 but most of which return to various parts of the mosaic. The loss of photo-electrons results in positive charges being built up on the mosaic approximately proportional in quantity at all points to the incident light flux. The scanning beam restores the positively charged mosaic elements to a potential which is fixed in relation to the anode potential. The build-up of the positive charge on any part of the mosaic takes place for the most part in a small fraction of the total frame-scan period which immediately precedes the scanning of that particular part. Thus the effective exposure time is very small, of the order of 1/250 sec; moving objects are therefore reproduced with good definition and an object in rapid movement produces a succession of separate sharp images. The removal of the integrated positive charges by the electron beam sets free equal and opposite charges on the signal plate which flow to earth through the signal resistance R and so produce a picture signal in the first valve V of the head amplifier.

The signal current produced by the Emitron for peak white of the optical image is about 0·1 μA. The noise associated with such a current is small compared with the r.m.s. noise current of the best wide-band amplifier. Hence the sensitivity of the tube would ultimately be limited by the ratio of the signal current to the amplifier noise current if it were not for the fact that at an earlier stage it is limited by spurious signals, collectively known as shading signals, which arise from the uncontrolled spread of secondary- and photo-electrons across the mosaic. The origin of these shading signals is closely

associated with the actual process of signal generation, and they can be avoided only by adopting a radically different method. All that can be done in this tube is to compensate for them by artificially produced waveforms which are mixed with the output signals from the tube. Unfortunately, the shading signals depend to some extent on the photo-electron emission and therefore change as the light distribution in the image changes. Thus, constant adjustment of the correcting signals is necessary during operation on a moving scene. As the illumination decreases, the shading signals become larger in relation to the picture signals and more difficult to correct, until finally the excessive shading usually determines the limit of satisfactory operation.

Of the photo-electrons liberated from the mosaic elements by the light of the image only a small proportion (less than 5%) are effective in generating a picture signal. Thus the tube is very inefficient, and in order to offset this disadvantage as far as possible a mosaic of large area and a lens of large diameter are used. This, in turn, results in a small depth of focus for normal scene illumination. In practice an illumination of some 300 lm/ft^2 and a lens aperture of *f*/3 are necessary on an average scene to give pictures reasonably free from objectionable shading. Illumination at this level is uncomfortable, and, even so, the depth of focus is very limited.

Another result of this mechanism of signal production is that at no point in the scanning cycle is a signal produced which has a fixed relation to "picture black." Hence black level in the reproduced picture is quite arbitrary. Advantages of the process are that the tube is quite stable to overload of light, and that the ratio of signal amplitude to light flux decreases with increasing brightness of the illumination falling on the mosaic. In other words, the reproduced signals have a low gamma (see Part I, Section 5) of about 0·7.

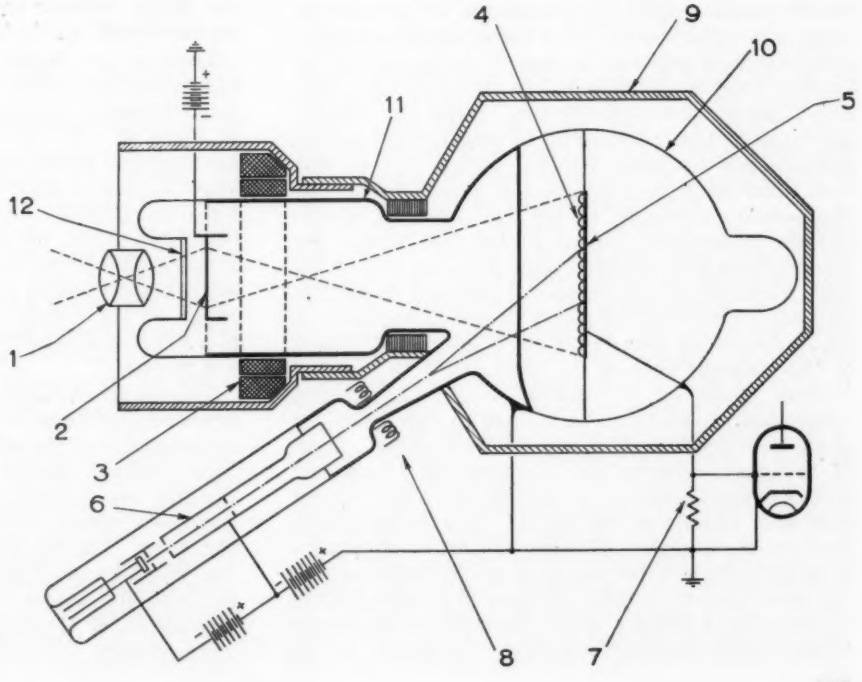
Finally, the Emitron is of an awkward shape to incorporate in a camera, and because of this and of its low sensitivity it has been found impracticable to use either a lens turret or telephoto lenses. Initially, the tube had a colour-response characteristic which was too sensitive in the red and infra-red regions to give pleasing reproductions, but an improved mosaic was developed early in its history to overcome this drawback.

From this brief summary it will be clear that the Emitron falls far short of the ideal tube specified in Part I, Section 5.

3 The Super-Emitron

After the Emitron had been in service for a time and the great attraction of outside broadcasts became obvious, there was an urgent demand for greater sensitivity to enable the scope of such broadcasts to be extended to functions where illumination was lower than could be reasonably provided in the studio. The first major step towards meeting this requirement was the development and introduction into service in November, 1937, of the Super-Emitron. As the name implies, this tube has a close family resemblance to the Emitron but its sensitivity is increased by the addition of the image section described in Part I [Section 3, Fig. 4(*a*)].

The original design of the tube is shown here in Fig. 2 to emphasize its evolution from the Emitron. Since the



2 *The Super-Emitron*

3 *The miniature Super-Emitron*

war, a scaled-down and improved design of the Super-Emitron and other tubes of the same general type has been developed. A photograph of the miniature Super-Emitron is shown in Fig. 3. As in the Emitron (Fig. 1) the Super-Emitron (Fig. 2) consists of a spherical bulb 10 with, in a side tube, an electron gun 6 which projects a focused beam of electrons that is scanned by the coils 8 over the mosaic surface 4 of the target 5. In this case the target is not photosensitive but highly insulating and a good secondary emitter. In place of the window of the Emitron another extension of the tube 11 is provided with a flat window 12 at the end. Inside this window is a transparent plate 2 on which a transparent conducting photocathode is formed on the opposite side to that from which the lens, 1, projects the optical image. The photo-electrons released by the light from the photocathode are accelerated by an electric field between the photocathode and the metal coating on the wall of the tube, which also forms the second anode of the electrostatically focused electron gun 6. These photo-electrons are accelerated to an energy of about 500 eV and focused by the magnetic field of the short coil 3 to form an electron image on the mosaic 4. The conducting transparent cathode may have three to four times the photo-electric efficiency of the Emitron mosaic. Each of the photo-electrons on impinging on the mosaic surface releases from 5 to 10 secondary electrons. Hence each unit of light in the optical image in the Super-Emitron results in about 20 times the number of electrons being liberated from the mosaic as would be liberated by the same amount of light falling on the photosensitive mosaic of the Emitron. In the generation of the picture signals these secondary electrons correspond to the photo-electrons in the Emitron and therefore the sensitivity of the Super-Emitron should be about 20 times as great and this, in fact, was found to be so. Part of this factor is spent in providing a more convenient and efficient optical system.

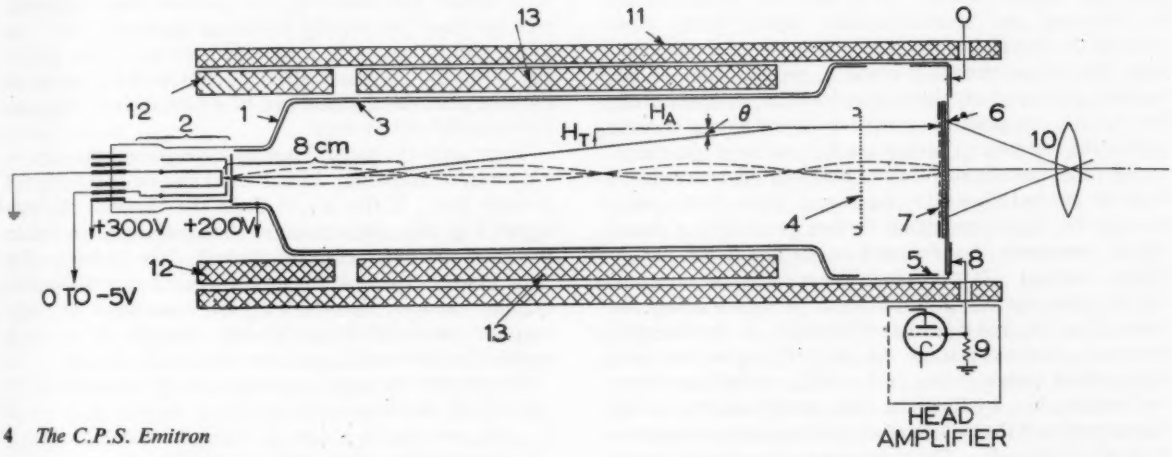
The photocathode is smaller in diameter than the mosaic of the Emitron; a short-focal-length lens of large aperture can therefore be used to give wide-angle pictures, and it is practicable to use telephoto lenses to give narrow-angle shots. With a 2 in lens at *f*/2 compared with a 6 in lens at *f*/3 in the Emitron the total light in the optical image will be a quarter as much. Thus the overall sensitivity of such a camera should be about five times as great as that of the Emitron, and it should therefore produce a satisfactory picture with a scene illumination of about 50 lm/ft^2. Also, because of the smaller diameter of the object lens, the depth of focus is greatly increased. Two great advantages have thus been achieved: a large increase in sensitivity and a useful increase in depth of focus. In other respects the performance is very similar to that of the Emitron; similar shading signals are produced and there is no true black-level signal. The signal gradation is similar to that of the Emitron and, for the same reason, gamma control is not possible. Definition is good, since the resolution of the electron image formed on the mosaic is very satisfactory and the focus of the scanning beam is as good as in the Emitron. The colour response is determined by the type of photocathode used and may be any one of those shown in Fig. 2 of Part I. One noticeable difference in performance is that the effective exposure time of the Super-Emitron pictures is longer than that of the Emitron, owing, it is believed, to the higher average initial energies of secondary- as compared with photo-electrons.

Tubes of this design are even more inconvenient to incorporate in a camera than the Emitron. The electron image formed on the mosaic is rotated through an angle of about 30° relative to the optical image so that the gun neck and mosaic must be rotated in the same sense about the axis of the image section. Also, the magnetic focusing field tends to spread into the path of the scanning beam and distort the raster, and stray fields from the scanning coils 8 tend to scan the electrons of the electron image slightly and so reduce the definition of the charge image on the mosaic. To reduce these effects to an acceptably small magnitude, elaborate magnetic screening 9 is necessary.

The smaller versions of this type of tube (Fig. 3) that have been developed since the war have had very similar sensitivities and characteristics. They have enabled a more compact camera to be designed around them but this has necessitated a reduction in photocathode size which reduces the amount of light accepted and the sensitivity. This has again to some extent been offset by the development of better photocathodes (Bi–Ag–Cs), at least for studio operation. Greater sensitivity, elimination of shading and a fixed black-level signal were, however, still badly needed.

4 The C.P.S. Emitron

As the initials imply, the mosaic of the C.P.S. Emitron is *cathode potential stabilized*. This method of operating the tube has been described in Part I (Section 4). It was first proposed in 1934 as a method of achieving the three desirable characteristics just mentioned (improved sensitivity, elimination of shading, and fixed black-level), and was incorporated in the orthicon developed in the United States before the war. This early work showed the validity of the method in reaching the desired result, but owing to inadequate technique in other respects at that time the performance of the orthicon was not very satisfactory, and in this country it did not find favour in competition with the Super-Emitron. Only after the war, by radical changes in design and improvements in technique, was it possible to incorporate the basic principle in the C.P.S. Emitron.



4 *The C.P.S. Emitron*

The tube is shown diagrammatically in Fig. 4. It consists of a cylindrical glass envelope 1, of diameter 2½ in, with a short neck, of diameter 1 in, at one end, in which a simple electron gun 2 is mounted. The indirectly heated cathode is held at or near earth potential, the modulator at a small negative potential and the accelerating electrode at about +300 V. This electrode has a small aperture, about 0·002 in in diameter, through which the electron beam is projected along the tube axis. Here the electron-beam velocity is slowed down a little by reason of the potential of the space, determined by that of the wall anode 3, which is held at about +200 V.

The beam travels at practically uniform velocity until it reaches the fine metal mesh 4. From this to the target 7 the electrons are decelerated until they reach the surface of the target with almost zero velocity. The electrons of the beam are constrained to move in cycloidal paths under the influence of a uniform axial magnetic field H_A of about 50 oersteds, produced by a current in the solenoid 11. This field brings the electrons to a focus at several points along the axis and finally on the surface of the target. The beam is scanned by a transverse magnetic field H_T produced by two pairs of saddle coils, one pair 13 being shown. The effect of the transverse field, which is from 5% to 10% of the axial field in strength, is to produce a resultant field with lines of force at an angle θ to the axis, such that $\tan\theta = H_T/H_A$, around which the beam electrons now spiral until they have passed through the deflecting fields. On emerging from the deflecting fields they again travel parallel to the axis of the tube until they arrive normally on the target surface. This normal incidence is an important condition for stabilizing the potential of the mosaic with reference to that of the cathode.

In order to compensate for misalignment of the electron gun with the magnetic field a small, steady, transverse magnetic field is applied by means of an adjustable direct current through two pairs of small coils 12, known as alignment coils. The effect of this may be visualized as lining up the emergent beam with the magnetic field, and it has a very marked effect on the beam focus and discharging efficiency.

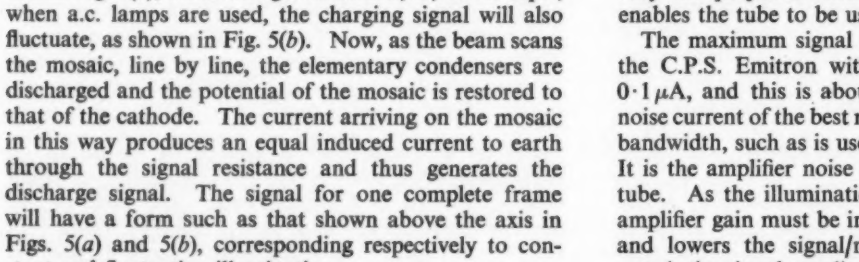
The electrode 5, a ring of metal on the tube wall surrounding the target, is held near earth potential and tends to keep the insulated mosaic surface at cathode, or earth, potential as the operating voltages are applied to the tube. As the electron beam approaches the target it is decelerated between the mesh 4 (held at the potential of the wall anode 3) and the mosaic surface 7. In the absence of light, and with proper alignment of the beam, it will charge the mosaic negatively and stabilize it at cathode potential. Under these conditions practically no beam electrons land on the mosaic; almost all are reflected and return to the electron gun along a path very close to their outward path.

The main function of the metal mesh 4 is to prevent positive ions formed in residual gas along the path of the electron beam from being attracted to the mosaic, where they would build up positive charges and give rise to spurious background signals.

The target 7 is of the general type described in Part I [Section 3, Fig. 3(*b*)]. Light from the optical image formed by the lens 10 passes through a transparent, conducting signal plate which is applied to a transparent dielectric, usually of glass, about 0·003 in thick, and then through a transparent photosensitive mosaic 7, from the free surface of which the photo-electrons are released. Improved techniques for making this transparent target have resulted in an increase in photo-electric efficiency by a factor of at least 5 compared with the pre-war target of this type; the actual value is about 20 μA/lm.

Mechanism of Signal Generation

The photo-electrons released by the incident light find themselves in a strong field accelerating them away from the mosaic surface. They also are controlled by the focusing and scanning fields, which direct them towards the gun end of the tube, where they are collected. Since the photo-electric current is proportional to the incident light and all these electrons are removed from the mosaic, the positive charges built up on the mosaic during the frame-scan period are accurately proportional to the integrated light. As the building up proceeds an induced current flows to the signal plate from earth through the signal resistance 9, thus producing a signal which represents the fluctuations in the total photo-electric current. If the image illumination is constant this charging signal will be constant, as shown below the axis in Fig. 5(*a*), but if the light fluctuates, as, for example, when a.c. lamps are used, the charging signal will also fluctuate, as shown in Fig. 5(*b*). Now, as the beam scans the mosaic, line by line, the elementary condensers are discharged and the potential of the mosaic is restored to that of the cathode. The current arriving on the mosaic in this way produces an equal induced current to earth through the signal resistance and thus generates the discharge signal. The signal for one complete frame will have a form such as that shown above the axis in Figs. 5(*a*) and 5(*b*), corresponding respectively to constant and fluctuating illumination.



5 *Charge and discharge of C.P.S. Emitron mosaic*
(*a*) Constant illumination.
(*b*) Fluctuating illumination.

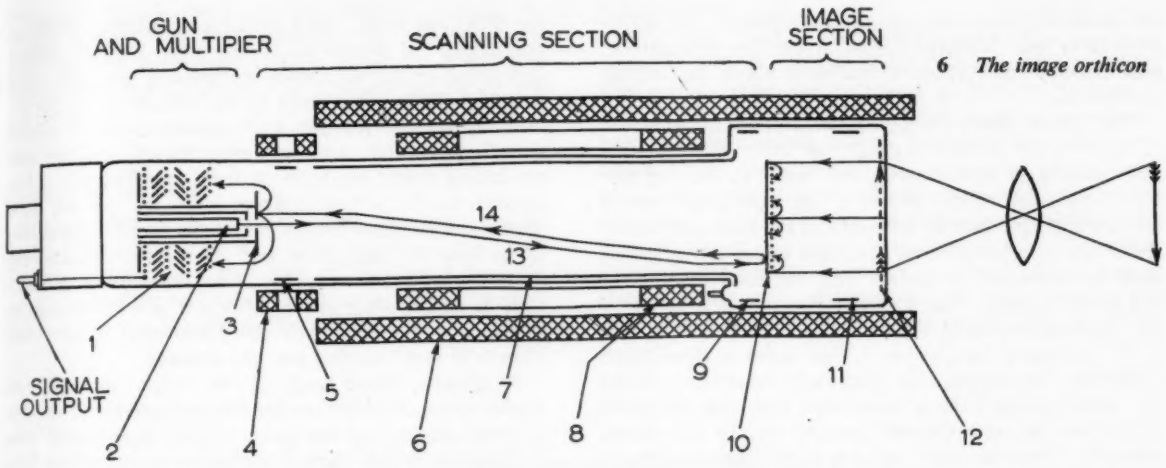
It is clear that the total integrated charge and discharge currents over a frame period must be equal. Also, the average signal current must equal the average charging current, i.e. the average photo-electric emission from the mosaic.

Since the photo-electrons and secondary electrons are prevented from moving about the mosaic uncontrolled, no spurious or shading signals are produced. Further, all photo-electrons are used to produce the picture signal, i.e. the tube is nearly 100% efficient, compared with probably less than 5% for the Emitron. Again, the signal amplitude is proportional to the incident light at any point in the image and is unaffected by the illumination at other parts of the mosaic, that is to say the tube signals have a gamma of unity.

At any point on the mosaic which has received no light, i.e. which is at "picture black" level, the mosaic accumulates no positive charge and hence receives no current from the scanning beam. This is the picture-black signal and is identical at all parts of the image. Also, it is the same signal current as that generated when the beam current is suppressed during the scan flyback intervals. In earlier versions of this tube these black-level signals were distorted by spurious electromagnetic pick-up from the rapidly reversing scanning fields, but by careful screening in a modified design of the tube it has been found practicable to reduce the pick up so that the black-level signal can be established during each line-scan flyback interval.

Thus, after the picture signals have passed through an a.c. coupled amplifier, the d.c. level can be re-established at each line. If this is not done the variable charging signal, Fig. 5(*b*), will appear in the reproduced picture in the form of horizontal bright and dark bands. This "line clamp" enables the tube to be used with rapidly varying incident illumination; for example, the image may be projected intermittently from a film, which enables the tube to be used for film transmission.

The maximum signal current that can be taken from the C.P.S. Emitron without losing definition is about 0·1 μA, and this is about 40 dB greater than the r.m.s. noise current of the best modern amplifier of about 3 Mc/s bandwidth, such as is used in conjunction with this tube. It is the amplifier noise that limits the sensitivity of the tube. As the illumination on the mosaic decreases the amplifier gain must be increased; this increases the noise and lowers the signal/noise ratio. Also, as has been noted, the signal amplitude is proportional to the image brightness ($\gamma = 1$). This is unsatisfactory for display on cathode-ray tubes, which strongly increase the gamma, and it is therefore arranged that the gamma is corrected in a special electronic circuit by which the lower level signals are progressively amplified to a greater degree. This can be done effectively since there is a good signal/noise ratio, no spurious signals, and fixed black-



6 *The image orthicon*

level signal; it has the advantage that the contrast of transmitted pictures can be adjusted to give the best pictorial effect.

Tube Performance

After all corrections have been applied the C.P.S. Emitron will give an excellent picture of an average scene illuminated with 5–10 lm/ft² and a lens aperture of *f*/2. At 1 lm/ft² the pictures will be quite acceptable, though noisy, and intelligible pictures can be transmitted with 0·25 lm/ft² and the same lens aperture. Thus a very large increase in sensitivity has been obtained over the Emitron and a fair increase over the Super-Emitron, while at the same time all shading has been eliminated and a fixed black-level and controllable contrast-law have been gained. The definition is excellent, the modulation of detail corresponding to 400 lines being about 75%. The colour response, which is close to panchromatic, is shown by curve (*c*) in Fig. 2 of Part I.

The tube has one major fault, namely that it is unstable to excessive overload of light. Thus if the mosaic is subjected to an intense light it may lose such a flood of electrons that it becomes strongly positive, to the extent that each incident electron can now liberate more than one secondary, thus making the surface still more positive until it reaches anode potential. The tube then ceases to function properly and cathode potential must be re-established on the mosaic to restore it to normal. This can be done manually in a few seconds and automatically in a fraction of a second, but although the trouble seldom occurs it is inconvenient and careful operation of the tube is necessary to prevent it.

5 *The Image Orthicon*

The image orthicon was developed in the United States during the war, in the first instance as a tube of maximum possible sensitivity though relatively poor picture quality. Its overall picture quality has gradually been improved without loss of sensitivity, and it is now used almost universally in the United States and very widely in Great Britain and other countries.

The tube is shown diagrammatically in Fig. 6. It will be seen to have a general resemblance to the C.P.S. Emitron but with two major differences: an image section as described in Part I [Section 3, Fig. 4(*b*)], is employed in the input, and the output is from a 5-stage electron multiplier that surrounds the electron gun. The optical image is formed on a transparent conducting photocathode 12; the photo-electrons liberated from the photocathode are then accelerated and focused on to the target 10. This is a thin semi-conducting glass diaphragm with a fine metal mesh stretched close to it on the side on which the photo-electrons impinge. The glass film is maintained at the potential of the cathode 2 of the electron gun by the scanning beam, as in the C.P.S. Emitron (see Part I, Section 4), and the potential at which the metal mesh is held is a few volts positive to this. Hence initially, most of the secondary electrons released from the glass surface are collected by the mesh, so building up positive charges on the condenser formed by the mesh and glass film. These positive charges leak through the semi-conducting glass diaphragm to the scanned side, where they are removed by the beam. The scanning beam 13 is focused by the solenoid 6, deflected by the coils 8 and aligned by the coils 4 in the same way as in the C.P.S. Emitron. However, in scanning the mosaic the beam loses electrons according to the charges on the target, and thus the reflected beam 14 is amplitude-modulated. It returns, almost along its outward path, to the limiting anode 3 of the electron gun, which it reaches with a fairly high energy. The front surface of this electrode is prepared as a good secondary emitter so that each primary electron liberates several secondaries. These are attracted by the first dynode of the electron multiplier 1 which surrounds the electron gun, and an electrode 5 on the wall of the tube, known as the "persuader," held at a potential negative in relation to the gun anode, helps to direct

the secondary electrons into the multiplier. The multiplier is of the "Venetian blind" type, the potential of each dynode being at about 300 volts above that of the earlier one.

The return beam current is multiplied by a factor of about 1000 but the signal/noise ratio of the multiplier output is substantially the same as that of the input, i.e. the return beam. The multiplier output current is passed into an amplifier of the necessary bandwidth but of relatively low gain, and hence the amplifier noise is very small compared with the noise inherent in the signal current. The r.m.s. noise current is given by the expression $(2eIf)^{\frac{1}{2}}$ where I is the beam current and f the frequency bandwidth. This noise is distributed uniformly throughout the frequency spectrum; unlike the noise arising from a wide-band high-gain amplifier which can be concentrated (peaked) in the h.f. range, where for the same r.m.s. value it is less objectionable to the viewer by a factor of 5–10 dB. The signal/noise ratio is smaller than it would be in an ideal tube because of the inefficient modulation of the beam. This may be 20% corresponding to peak-white signal, so that the current contributing to noise is four times the signal current in peak-white areas, and five times in black areas of the picture. Further noise arises from the random fluctuations in the charges stored on the mosaic. As pointed out in Part I (Section 3), the capacitance of the storage target is small; the small charges integrated on it, and in particular the small number of photo-electrons required to produce these charges, give to the image orthicon, even under the best conditions, a signal/noise ratio that is not as good as could be desired. Efforts to improve it have been directed to increasing the capacitance of the storage target and improving the beam modulation.

Picture Contrast

The tube may be operated in either of two ways, or in a combination of them. In the first, the elementary target condensers are not allowed to be completely discharged by the photo-electrons. Hence substantially all secondary electrons are collected by the mesh and the charges built up by the photo-electrons on the glass film are closely proportional to the distribution of light in the original image. Thus the picture signals have a gamma of near unity which has to be corrected to be suitable for display on a c.r. tube. However, to ensure that the target does operate in this way the mosaic capacitances can seldom be used to full advantage, and when gamma correction is applied, the signal/noise ratio, already low for that reason, is made still worse. Hence in this mode of operation the tube produces pictures of good gradation but poor signal/noise ratio.

In the second way, more light is used, and correspondingly more photo-electrons fall on the target; the condensers then may be fully discharged, and a uniformly white signal might be expected. However, the areas of the target corresponding to white areas of the picture receive more primary electrons and lose more secondaries than the dark-tone areas. So a dynamic equilibrium is set up, the degree of discharge of any one mosaic element depending on the secondary electrons it loses and those it collects from other parts of the mosaic. The charges built up on the mosaic, and consequently the picture signals generated, are not proportional to the light producing them; the tube, in fact, operates with a low gamma which is not uniform over the picture area. These operating conditions enable the target capacitances to be used to best effect and the best obtainable signal/noise ratio to be reached. Also, the effective exposure time is small, since the equilibrium conditions can be attained in far less than the frame-scan period, and objects in rapid motion are well defined.

In general, those parts of the target on which the darker areas of the image are focused operate in the first of these modes and the more brightly illuminated areas in the second, and there is a continuous transition from one state to the other. This provides an automatic gamma control of a rather crude type which is useful on scenes of very widely varying light values. The tube is also completely stable to light overloads, since the target cannot be driven to a potential higher than that of the metal mesh.

Shading

This method of operation leads to some undesirable results. The rain of secondary electrons falling back on areas of the mosaic immediately surrounding a white area causes depression of the signal from these surrounding areas, thus giving the effect of a dark shadow surrounding a white area. While this gives an appearance of enhanced definition it also distorts the picture gradation. If the brightness of the white area is increased the surrounding shadow is deepened and a very bright object appears surrounded by a deep shadow in which no picture detail is visible. These effects require very careful scene illumination with very limited contrast, and this involves working on the linear part of the characteristic, where the signal/noise ratio is poor.

Another source of shading and variation in the signal-black level is non-uniform multiplication of the return electron beam. During the scanning cycle the return beam scans a raster on the first electron-multiplier dynode which is also the accelerating electrode of the gun. The beam is slightly out of focus at this point but some electrons nevertheless pass through the aperture in this dynode at one point in the cycle and produce a diffuse white spot. Similarly, any variation in multiplication resulting from the beam following different paths through the multiplier results in picture-shading signals.

Black Level

Because of the redistribution of secondary electrons on the target the potential of areas corresponding to "picture black" will vary according to the supply of secondary electrons from neighbouring areas. Hence, the picture-black signal level is not constant but is

approximately the same as that generated during the flyback periods, when the electron beam is prevented from reaching the target surface either by a negative bias-pulse on the target mesh or a positive pulse on the gun cathode.

General Characteristics

The temperature at which the tube operates must be closely controlled, since it governs the conductivity of the glass of the target; definition will be lost if the tube is too hot, and lag will appear if it is too cold. If a fixed image is allowed to fall on the photocathode for more than a few seconds a replica of the image often becomes "printed" onto the target and continues to be reproduced for some time. Hence care must be taken in operation, particularly with old tubes, to avoid leaving the camera aligned on a stationary scene for more than a few seconds.

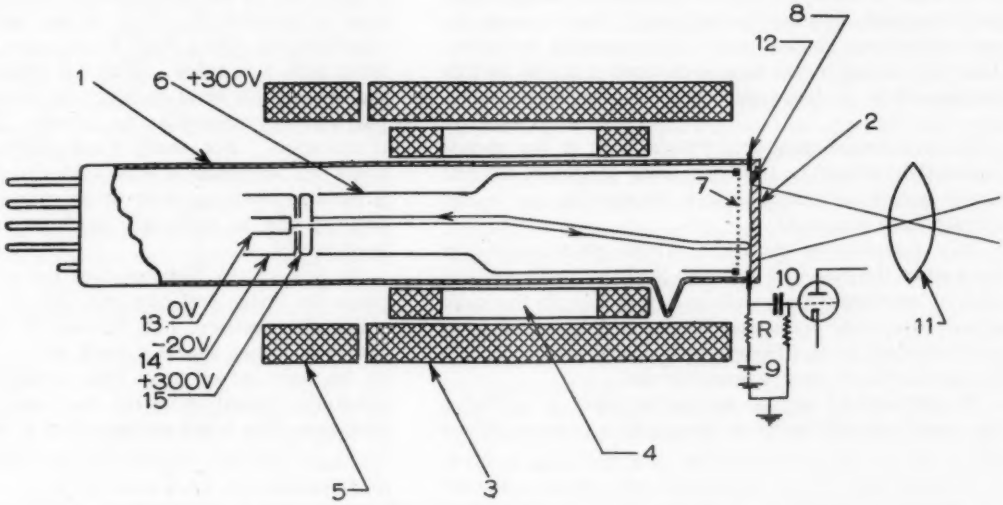
The performance of the tube may be summarized by saying that it has a very high sensitivity, giving a good picture with an illumination of 1 lm/ft² on an average scene and a recognizable picture with one-tenth of this; it is substantially stable to light overloads and will give reasonable pictures where the scene contrast is high. Very careful lighting and low contrast are necessary for good-quality pictures, for otherwise contrast is too artificial. The tube gives, at best, a poor signal/noise ratio, an indeterminate black-level, and appreciable picture shading.

Colour Response

The colour response of the image orthicon is of the type shown in Part I, Fig. 2, curve (*c*), for Bi–Ag–Cs and is a close approach to panchromatic.

6 The Vidicon

This tube, with its operating coils, has much in common with the C.P.S. Emitron except that a photoconductive target, as described in Part I (Section 3, Fig. 5), is used instead of a photo-emissive mosaic. In the example shown in Fig. 7 the tube 1 is small, only about 1 in in diameter and 6 in in length, and the focus coil 3, scanning coils 4 and alignment coil 5 are correspondingly small. The electron gun comprises cathode 13, modulator 14, and anode-limiter 15. The wall anode in the Vidicon is a thin metal cylinder 6, fitting closely to the walls of the glass tube and closed at the end near the target with a fine metal mesh 7 which maintains a uniform field between it and the target 8. The target is a transparent conducting film (the signal plate) on the internal surface of the end window 2 of the tube formed by depositing a thin layer of photoconductive material—amorphous selenium or antimony trisulphide. The light from the optical image is projected by the lens 11 through this transparent target, producing conductivity to varying degrees in the photoconductive material. The front, or scanned surface, of the photoconductive layer is stabilized by the beam at the potential of the cathode 13 of the electron gun, which is usually zero, and the signal plate is maintained at a positive potential of 10–40 volts by the potential source 9 feeding through the resistance *R* the annular metal ring 12 which is in contact with it. The signal is fed to a wide-band amplifier of high gain and low noise (as used with all tubes in which the signal is taken from a "signal plate") through the condenser 10. In the areas exposed to light the potential difference maintained across the layer causes a current to flow from the signal plate to the scanned surface, but no current flows to the target through *R* as a result of this charge transference. That is, there is no charging signal as there is in those types of pick-up



7 *The Vidicon*

in which the target loses electrons as a result of the charging process. The positive charge transferred across the photoconductive layer is removed at each scan by the beam and an equal and opposite charge flows to earth through R, so producing the picture signal.

Since the photoconductive layer must be very thin in order to enable the light to penetrate right through it, and since these materials have very high dielectric constants, the capacitance per unit area is very much greater than that of the C.P.S. Emitron target. Hence the p.d.'s on the mosaic are very small for the same charges and signal currents, and so the discharging action of the beam is relatively inefficient. This would result in serious lag if the target of the Vidicon were of the same area as that of the C.P.S. Emitron, and it is therefore made much smaller (about 3 cm^2, compared with 15 cm^2) to keep the capacitance per picture point approximately the same. The small size of the Vidicon is dictated primarily by this consideration; a large tube would give unacceptable lag.

The conduction produced by the light in the photoconductive materials available lasts longer than one frame period and there is thus appreciable lag in the picture from this cause.

Any variation in thickness of the photoconductive layer or of the potential at which the front surface of the layer is stabilized will result in a variation in the dark signal over these areas and hence shading and a non-uniform black-level. These effects must be minimized as far as possible by care in manufacture.

As the voltage applied across the layer is increased the signal strength increases but so do any non-uniform effects such as those referred to above. Also, when the potential across the layer exceeds about 40 volts the dark current begins to increase abnormally rapidly relative to the signal current, and noise, background and shading become unacceptable.

This tube is completely stable to light overloads and has a gamma of about 0·7. The definition obtainable is quite good and comparable with the best achieved with other types of tube. The colour response of the antimony-trichloride target is a reasonable approach to panchromatic, though rather deficient in the red region.

The main limiting factor in the performance of this type of tube is lag, which is due partly to the inevitable high capacitance of the target but still more to the inherent lag in the photoconductive effect. As the light level is reduced the effect of lag becomes more pronounced and sets a limit to the sensitivity of cameras fitted with such tubes. With full optical aperture of *f*/2 the lowest light level at which lag is tolerable for most purposes corresponds to about 20 lm/ft^2 incident illumination. For really good-quality pictures several times this illumination is necessary to overcome lag, but if pictures involving little or no movement are required and lag can be tolerated, much higher sensitivity can be achieved.

At present the Vidicon does not seem likely to displace the image orthicon or C.P.S. Emitron for entertainment television, but, because of its small size and low cost, it may enable a small, cheap television channel to be built which may find applications in what is generally termed industrial television, i.e. where high picture-quality is not so important as size and price.

OBITUARY

REGINALD FALSHAW

Reginald Falshaw, who died on the 9th November, 1954, was born on the 22nd June, 1872. He received his general education at Scarborough and Leeds Grammar Schools, his engineering education at Leeds Mechanics Institute, and his practical training with Cuttriss Wallis and Co.

In 1894 Mr. Falshaw started on his own account as an electrical contractor in Harrogate. His business expanded rapidly and he became well known as a specialist in large private installations. He carried out electrical installations in almost every great mansion in Yorkshire, including the Bishops' Palaces at York and Ripon, Ripley Castle, Hazelwood Castle, Rudding Park, Bramham Park, Thirkleby Park, Clumber Park, and the Halls at Bolton, Ganton, Copgrove, Farnley, Leathley, Kilnwick Percy, Aldborough, Nidd, Middlethorpe and Arthington. He also equipped many smaller country houses, churches and halls. His well-merited prestige as a first-class electrical engineer and contractor grew, and in 1926 he formed a company, R. Falshaw, Ltd., of which he was governing director, to control his business. Shortly before the Second World War the firm moved into new premises, a manager was appointed, and Mr. Falshaw went into semi-retirement. He still attended his office, but gave to it less of his time and energy than previously. However, after the death of his manager in 1948 he returned to more active work, until in the early 1950's he became considerably depressed by the death of his wife; his health failed, and he withdrew from contact with the firm, which closed down in 1954. From that time until his death, he was almost a recluse.

As an employer, Mr. Falshaw was fair and understanding; the service of some of his employees who

remained with him from 30 to 50 years, testifies to these human qualities. The electrical world has by his death lost a pioneer, who for 60 years was held in high esteem as an example of the individualistic electrical engineer.

He joined The Institution as an Associate Member in 1933 and was elected a Member in 1943. W. H.

JAMES KEITH GILLETT

James Keith Gillett, M.Sc.Tech., who died on the 17th November, 1954, was born on the 23rd October, 1901, in Chorley, Lancashire. He went to Manchester College of Technology from Chorley Grammar School in 1919, and gained a B.Sc.Tech. degree in 1923 and an M.Sc.Tech. in 1928. Two years later, having completed the College Apprenticeship Course with the Metropolitan-Vickers Electrical Co., he became Technical Assistant to Dr. B. L. Goodlet on high-voltage research, and was later employed in the Company's Distribution Department as Sectional Engineer.

In 1932, Mr. Gillett went to South Africa to join the staff of the Victoria Falls and Transvaal Power Co. in Johannesburg as a distribution engineer, but resigned in 1942 to join the South African Naval Service and in due course rose to the rank of Electrical Lieutenant-Commander with an appointment as Degaussing Officer, Durban.

After demobilization in 1946, he returned to his previous employers for two years before joining the Anglo-American Corporation of South Africa as an Electrical Assistant in January, 1948. From 1948 to 1951 he was closely associated with electrical developments in the new gold mines of the Anglo-American Group in the Orange Free State and with the planning of the distribution for the all-electric town of Welkom. In both activities he left his mark. In 1951 he became Assistant to the Consulting Mechanical Engineer in the Diamond Section of the Corporation, and it was during the testing of an electric locomotive on the property of the Consolidated Diamond Mines of South West Africa that he met with the accident which caused his death.

Keith Gillett will be remembered by his numerous friends in the engineering field as a man with a very definite viewpoint. He never followed popular opinion; in fact he delighted in aligning himself on the opposite side—a course which frequently proved correct. His death has made a large gap in the engineering circle of Johannesburg, as indeed it has elsewhere, and his passing is widely mourned. He is survived by his widow and two children.

He joined The Institution as a Student in 1920 and was elected a Graduate in 1928, an Associate Member in 1931 and a Member in 1940. He was a very active member of the South African Institute of Electrical Engineers, serving on the Council from 1939 to 1942 and from 1951 to 1954, and presenting several papers. He was also a member of the American Institute of Electrical Engineers. A. S. A.

CHRISTOPHER MARK MAYSON

Christopher Mark Mayson, who died after a long illness on the 1st March, 1955, was born on the 4th May, 1872. He was educated at St. Bees School, Cumberland, and received his practical training at the St. Rollox Locomotive Works of the Caledonian Railway Co., after which he took the three-year course in Physics and Electrical Engineering at the Central Institution, London.

His first appointment was in 1896, as Electrical Engineer to the Whitehaven Corporation Electricity Works, later renamed the Whitehaven Borough Council Electric Lighting Department, where he had already served as an improver for a year. In 1899 he left Whitehaven to join the Charing Cross Co. as Stations Engineer. This Company, which had originally given supply only in the very small area of St. Martin's, had obtained the Strand order and was expanding rapidly. At this time its station was on the river bank at Lambeth, generating at 1 000 volts d.c., and its only substation was in Maiden Lane, where the voltage was converted by motor-generators for supply purposes to 200 volts on a 3-wire system. Mr. Mayson's first job was the equipment of another substation at Shorts Gardens. The company then obtained the City of London order, which necessitated much new work, and for this he was responsible. An up-to-date station was erected at Bow, to generate 3-phase 50 c/s current at 11 000 volts and supply seven substations in the City and West End, which converted by motor-generators to a 3-wire 400/200-volt system in the City, and a 200/100-volt system in the West End. This was the first plant of its kind in this country and aroused much interest, but before any of it could be put into operation the substation in Maiden Lane was burnt to the ground. Neither the Engineer-in-Chief nor Mr. Mayson left the premises for two weeks on that occasion; pioneers in electric supply expected that sort of life in those days. In 1901 the Company decided, in order to satisfy the requirements of the London County Council, to have a separate supply system, in generation as well as distribution, for theatres and public buildings. Generation was to be by Diesel plant in the Shorts Gardens and St. Martin's Lane substations with direct-coupled d.c. generators, and Mr. Mayson was at once in his element. He joined the Diesel Engine Users' Association, read many papers at the meetings, and in due course became the Association's President. In later years he had under his direct control two of the largest Diesel engines then known, and may be aptly said to have enjoyed that distinction. After the First World War it was decided to change over gradually to a.c. 3-phase 400/230-volt supply by building transformer stations where possible and running 11 000-volt ring mains, but to meet the then pressing demand it was found necessary to erect automatic d.c. plant temporarily, and so to arrange it that a.c. plant could be readily substituted. The sites chosen (outside those in large consumers' premises) were under the public squares, and the agreement of the Local Authorities was obtained in

return for the Company's offer to erect lamp-posts and light the squares free. Under this arrangement sub-stations were immediately erected under Soho Square and Leicester Square. From 1920 onwards Mr. Mayson was virtually Deputy Chief Engineer although he never took the title, preferring that of Stations Engineer. He never became Engineer-in-Chief because he was due to retire shortly after his Chief's retirement in 1935.

To survivors of the Old Brigade who at the turn of the century laboured, sometimes literally night and day, to get the electricity supply of London on a sound footing, the death of Christopher Mayson leaves a sense of great personal loss.

Mr. Mayson was a keen freemason, and was Master of the Caveac Lodge in 1934. He was also a musician—in particular an accomplished amateur organist. Throughout his life he was a devoted churchman and took an active interest in the affairs of his church. He retired to Swanage in 1937 and thereafter devoted most of his time to gardening. He is survived by his widow and a son.

He joined The Institution as a Student in 1893 and was elected an Associate in 1896, an Associate Member in 1899 and a Member in 1920. W. B. T.

THOMAS FREDERICK GRANT SHEPHARD

Thomas Frederick Grant Shephard, who died on the 17th February, 1955, was born on the 19th December, 1876. He received his technical education at Finsbury Technical College, London, and served an apprenticeship with the W. R. Sykes Interlocking Co., the pioneers in the famous Sykes lock-and-block train-signalling system, which was adopted at the beginning of the century by the London and South Western and other railway companies in this country and later introduced on many oversea railways.

In 1898 Mr. Shephard received his first appointment, that of switchboard attendant with the St. James's and Pall Mall Electric Light Co. Later that year he returned to the W. R. Sykes Interlocking Co., and was in charge of the test room and experimental department until 1901, when he left the company and went to Russia, working on the design and erection of railway signal installations. He joined the Bombay, Baroda and Central India Railway Co. (now the Western Railway, Indian Government Railways) in 1906, as Assistant Telegraph Engineer. At that time there were hardly any telegraph circuits on the railway and no general electrical installations.

In the 30 years of his service with the B.B. and C.I. Company, Mr. Shephard was engaged on the development of telegraphs, the installation of the traffic-control telephone system and of automatic telephones and power stations at various parts of the railway. In collaboration with Mr. A. Whitney, who was the company's Signal Engineer, he developed the Whitney and Shephard system of station-master's control. With the increasing application of electrical developments, a separate department was formed and he was made a Divisional Electrical Engineer. In 1931 he became Chief Electrical Engineer, and held that position until he returned about five years later.

Mr. Shephard will be remembered not only for his work but also for his keen interest in the welfare of his staff and in their social and athletic activities.

He joined The Institution as an Associate Member in 1912 and was elected a Member in 1923. H. C. T.

ALFRED SPEIGHT

Alfred Speight, I.S.O., who died on the 26th March, 1955, was born on the 24th November, 1883, in Yorkshire. He received his general education at Bell View Science School, Bradford, and his engineering education at Bradford Technical College and Leeds University. He started his engineering career in 1900 as an apprentice with the National Telephone Co. but resigned in 1904 and went to Canada and the United States, spending nine months on exchange construction and maintenance with the Bell Telephone Co. In 1905 he rejoined the National Telephone Co. at Bradford. After five years he was promoted to District Electrician for East Yorkshire with headquarters at Hull, and in 1911 was transferred to the Engineer-in-Chief's office of the company. At the end of 1911 came the transfer of the National Telephone Company's undertaking to the Post Office, but Mr. Speight was retained by the company for a year on arbitration work, and did not join the Post Office until January, 1913, when he was appointed to the Engineer-in-Chief's staff.

From 1916 to 1919 Mr. Speight served with the Royal Engineers, attaining the rank of Acting Captain. On demobilization he returned to the Post Office, and was engaged on maintenance problems and procedure. He quickly became an authority on this subject, and will be remembered particularly for his part in the development of routiners for preventive maintenance. In 1933 he was promoted to the rank of Assistant Staff Engineer in the Organization and Efficiency Branch, and three years later to that of Staff Engineer in the same Branch. In the autumn of 1933 he paid a second visit to the United States and Canada—this time as a member of a mission from the Post Office—to study American methods and to exchange ideas on telephone problems. In September, 1939, he became Chief Regional Engineer of the newly formed Midland Region, and remained there until his retirement on the 30th June, 1947.

Mr. Speight had all the forthrightness of his native Yorkshire, coupled with a passion for detail and much patience in probing to the core of a problem. He received the award of the I.S.O. in 1946.

He joined The Institution as an Associate Member in 1921 and was elected a Member in 1933. G. F. O.

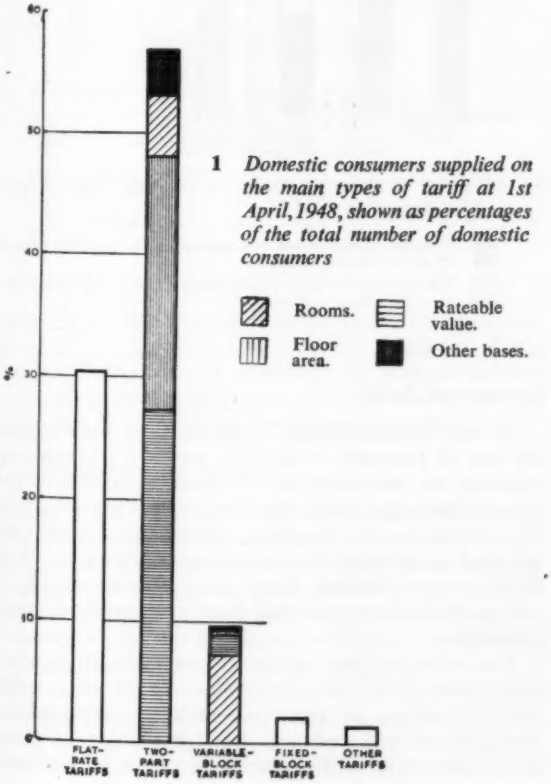
ELECTRICITY TARIFFS

Some New Standards

A. O. JOHNSON, B.Sc.Tech., *Member*
N. F. MARSH, M.A., *Member*

A paper with the title "The Standardization of Retail Electricity Tariffs" was presented by Mr. Johnson and Mr. Marsh at a Joint Meeting of the Utilization and Supply Sections of The Institution on the 17th March, 1955. Its purpose was to show the steps taken since Vesting Date (1st April, 1948) to standardize and simplify retail electricity tariffs as laid down by the Electricity Act, 1947, and to discuss the recommendations of the Retail Tariffs Committee. The paper itself was published separately in March, 1955, and it will soon be republished in Part A of the Proceedings. Here Mr. Johnson and Mr. Marsh, who are with the North Western and North Eastern Electricity Boards respectively, give a brief indication of these recommendations with comments on one or two features of them.

THE thorny problem of electricity tariffs has been considered by a number of Committees set up by the Electricity Commissioners and other bodies between 1925 and 1946. In 1948 the Central Electricity Authority and the Area Boards set up the Retail Tariffs Committee to consider the whole tariff situation as it existed at Vesting Date and to make recommendations for some uniformity in future tariff structures. The paper sets out in some detail the recommendations of that committee with regard to domestic, industrial, commercial, combined domestic and commercial, and farm tariffs, and in this article we shall use the same headings for our consideration of the subject.



1 *Domestic consumers supplied on the main types of tariff at 1st April, 1948, shown as percentages of the total number of domestic consumers*

Domestic Tariffs

Fig. 1 shows the number of domestic consumers supplied under the main types of tariff which existed at Vesting Date, and it will be noticed that the great majority were supplied either on two-part tariffs or on separate flat rates for lighting, heating and other purposes. So far as two-part tariffs were concerned, the most popular bases of assessment for fixed charges were rateable value and floor area. Rateable value was generally used by municipal undertakings, who had ready access to the rating assessments within their own particular districts, and floor area was, by and large, preferred by company undertakings whose individual areas covered more than one rating-authority district, usually with considerable variations in the level of rating assessments between authorities.

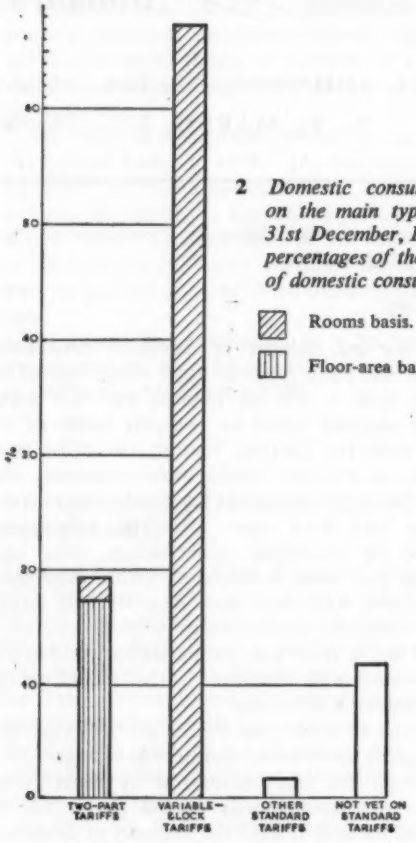
It is interesting to note from Fig. 2 (p. 514) that the pattern of domestic tariffs in the country has changed considerably through the implementation by most Area Boards of the recommendations of the Retail Tariffs Committee. At the end of 1953 the majority of domestic consumers (67·5%) were supplied on variable-block tariffs, the size of the various blocks being based on the number of rooms in the premises, and 19·3% only were supplied on two-part tariffs, mostly based on floor area. It is true that at that time 11·6% of domestic consumers still remained to be changed over to standard tariffs and the general picture may be altered somewhat when this is done.

It will be seen that the rateable-value basis of assessment has disappeared completely from the standard domestic tariffs, and that the rooms basis is now the most widely adopted. One advantage gained is that it is fairly easy to quote to a consumer his assessment from a description of the rooms in his house, although some difficulty may be experienced in the assessment of marginal rooms such as kitchenettes, sculleries, attics and cellars. Incidentally, the rooms basis is widely used on the Continent for domestic tariffs.

Industrial Tariffs

The Retail Tariffs Committee recommended that a variable-block tariff should be available for the smaller industrial consumers and a two-part maximum-demand type of tariff for the larger industrial consumers, and this recommendation has generally been followed by those Boards which have so far introduced standard industrial tariffs. It was recommended that the primary block in a variable-block tariff should be based either on assessed maximum demand (not measured maximum demand) or on floor area, and, as will be seen from Fig. 3, this recommendation has been followed for 21·7% of the industrial consumers whose tariffs were standardized by the end of 1953. Some Boards felt, however, that to introduce a variable-block tariff of this type in their own Area would cause considerable disturbance to consumers' accounts because the majority of supplies to the smaller industrial consumers had been given on fixed-block tariffs prior to Vesting Date; they therefore introduced standard fixed-block tariffs in their areas, and at the end of 1953 17·6% of the total industrial consumers were supplied on such tariffs. At that time, also, 8·9% of the total industrial consumers—mainly the larger ones—were supplied on measured maximum-demand tariffs and these consumers were using 48% of the total industrial energy consumed.

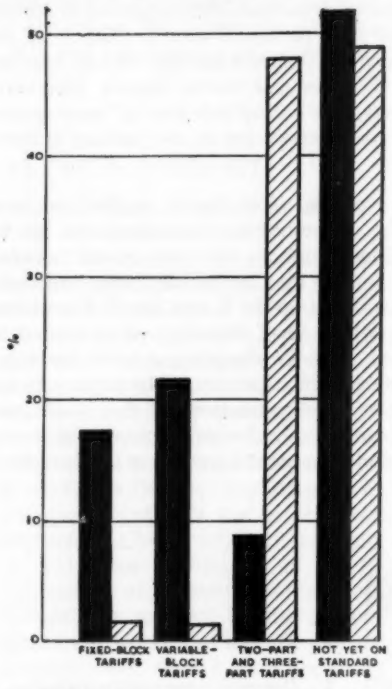
Fig. 3 also shows that there is still a very large number of industrial consumers not yet supplied on standard tariffs, and the balance between the various types of tariff may be considerably altered when the remainder of these consumers have standard tariffs available.



2 *Domestic consumers supplied on the main types of tariff at 31st December, 1953, shown as percentages of the total number of domestic consumers*

Rooms basis.

Floor-area basis.



3 *Industrial consumers supplied on the main types of tariff at 31st December, 1953*

Number of consumers as a percentage of the total number of industrial consumers.

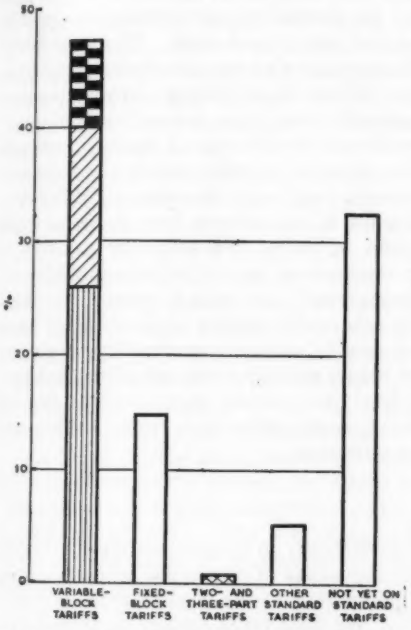
Energy consumed as a percentage of the total energy sold to industrial consumers.

Commercial Tariffs

As with domestic tariffs, there has been a swing from the use of two-part or flat-rate tariffs for commercial premises to variable-block or fixed-block tariffs, and Fig. 4 shows that at the 31st December, 1953, 47·2% of the consumers on standard commercial tariffs were supplied on variable-block tariffs, most of them based on floor area or installed load. At that time 32·1% of commercial consumers still had no standard tariffs available.

The main problem in the introduction of standard commercial tariffs has been to cater for the widely differing classes of premises, such as shops, offices, hospitals, schools, colleges, public buildings and places of worship. The tariffs really have had to be "residual"

ones catering for all premises not covered by the domestic, industrial or farm tariffs. Where the floor-area basis has been used for the assessment of the variable blocks in commercial tariffs, separate rates of assessment have normally been used for the different classes of premises in order to take account of the varying demands for



4 *Commercial consumers supplied on the main types of tariff at 31st December, 1953, shown as percentages of the total number of commercial consumers*

Maximum power required. Floor area. Installed load. Measured maximum demand.

electricity in relation to floor area. If this were not done it would be difficult to find a basis suitable for all the widely differing types of premises. Continental practice also tends to favour floor area with a number of rates of assessment to cover respective types of premises.

Commercial Catering Supplies

In the paper we strongly advocated special flat-rate or fixed-block tariffs with only a small differential between the highest and lowest rates, to encourage the commercial catering load. We pointed out that although many of these supplies do not show very good load factors individually, there is considerable diversity between the demands made on the electricity supply system; this is illustrated by Fig. 5, which indicates typical load diagrams for a fish-frying installation, a bakery, a school kitchen and a restaurant. In such a competitive business it is essential to have a simple tariff which is easily understood.

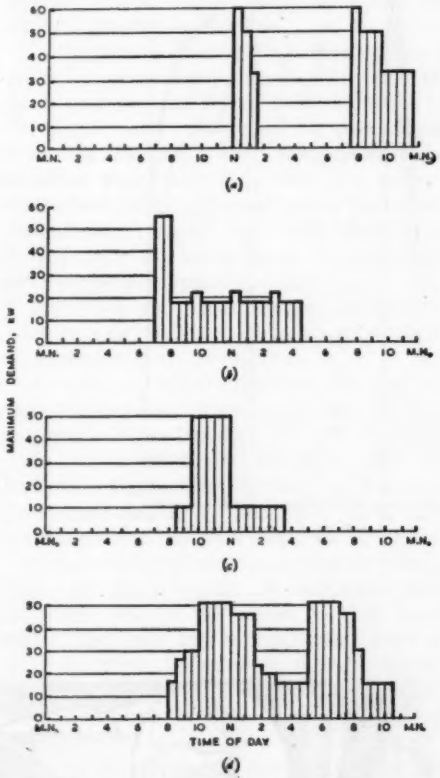
Combined Domestic and Commercial Premises

In general, combined premises, which consist mainly of small shops with living accommodation above them, are dealt with on a combined assessment under the domestic and commercial tariffs, and no special problems arise.

Farm Tariffs

It has been difficult to find a suitable basis of assessment for two-part or block tariffs for farms. The Retail Tariffs Committee recommended that the assessment of the farmhouse should follow the domestic tariff and that the basis for the farm buildings should be either assessed maximum demand or floor area. There are, however, a number of difficulties in the adoption of either of these, particularly the floor-area basis, with which awkward points arise concerning the inclusion or exclusion of open-sided buildings such as cart sheds, Dutch barns and covered crew-yards, and with portable poultry-houses and pig and poultry arks.

By the end of 1953 nine Area Boards had standardized their farm tariffs; in four Areas the farm premises assessment was related to installed load and in the others to assessed demand, farm acreage, floor area of farm



5 *Load diagrams of typical commercial catering installations*

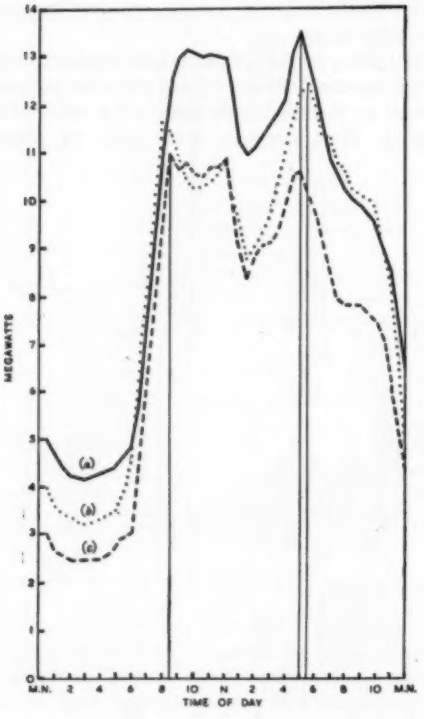
(*a*) Fish-frying installation. (*c*) School kitchen.
(*b*) Bakery. (*d*) Restaurant.

buildings, maximum power requested and transformer capacity, respectively.

Farm tariffs are still somewhat confused and it is probable that further alterations will be made when the Area Boards have had more experience with the operation of their standard farm tariffs.

Restricted-Hour Tariffs

The paper includes a Section dealing with the all-important subject of restricted-hour tariffs, and we pointed out that these have to be designed to keep supplies off the peak-demand periods of both the Area Board concerned and the Central Electricity Authority. Fig. 6 shows that these periods do not always occur at the same times, and, in the examples shown, one Area Board had its peak demand at 5.30 p.m. and another at 8.30 a.m.; the national system peak for that year occurred at 5.0 p.m.



6 *System load curves*
(*a*) National curve.
(*b*) and (*c*) Typical Area Board curves.

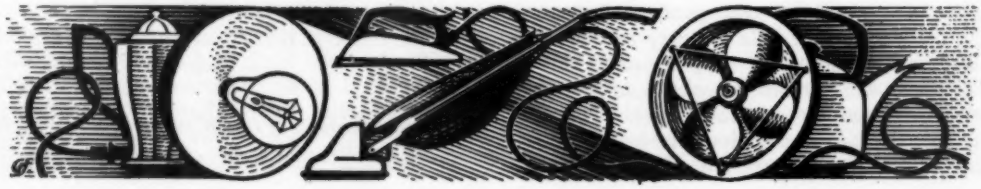
In general, however, it should be possible to offer attractive charges for supplies taken only between 6.0 p.m. and 7.0 a.m. (with small variations to suit individual Boards), and it should usually be possible to allow a mid-day boost from about 12.30 p.m. to 3.30 p.m. where required for thermal-storage installations, and to permit unrestricted use at week-ends. Thermal-storage heating and battery charging can usually be supplied at lower rates than off-peak flood-lighting and advertisement signs, which generally have much shorter hours of use.

The paper mentions the difficulty of quoting restricted-hour tariffs for domestic supplies where the follow-on rate of the domestic tariff is of the order of 1d./kWh or less; such reduction of this already low charge as could be offered would be more than offset by the cost of supplying and maintaining time switches and additional meters. It is suggested that with domestic two-block tariffs, the only practicable method of encouraging water heating (which usually operates on the thermal-storage principle) is to reduce the follow-on rate after reaching a consumption level that would cover normal use for lighting, cooking, radio, television, irons, kettles, and occasional space-heating.

General

There is great difficulty in introducing standard tariffs affecting many thousands of consumers without causing considerable disturbance to the level of their individual electricity bills. We were taken to task by several contributors to the discussions of the paper in London and Newcastle for having paid too much attention to this feature of introducing standard tariffs, but we maintain that the question of disturbance to individual consumers' accounts must be given considerable thought in the introduction of standard tariffs; otherwise some consumers' accounts might be increased by as much as 200–300%.

Once Area Boards have overcome the initial hurdle of introducing their own standard-tariff structures with the least disturbance to individual consumers' accounts, they will be able to examine the tariffs of neighbouring Boards whenever their own are due for review, and thus endeavour to bring them more into line. This process would result in the progressive ironing out of small tariff differences between Boards.



TELEGRAPH CODES

An Informal Lecture to the Radio Section

On the 2nd May, 1955, Mr. H. V. Higgitt, late of the staff of Cable and Wireless, delivered an informal lecture entitled "A Simple Introduction to Telegraph Codes" before a meeting of the Radio Section. A summary of the lecture, and of the subsequent discussion, appears below.

MR. HIGGITT began by saying that the term "telegraph codes" is used rather loosely in practice, and he proposed to define it for the purpose of his talk as "sequences of simple changes of some natural phenomenon to represent characters." The phenomenon can take innumerable forms.

Ideas for the electric telegraph became extensive in the 1830's and considerable practical progress was made in the 1840's. The work of Morse in America is classical; there were also several inventors in Great Britain and Germany, each devising his own code. Morse's work, using short/long elements and a 2-position or binary code was, on the whole, more successful than the European efforts, which were based mainly on the use of plus and minus currents to provide two kinds of elements, resulting in a 3-position or ternary code. These two systems survive, with modifications, to-day as the international Morse code and cable code respectively. Both make use of the same permutations of two kinds of elements (dot and dash) adopted at a German–Austrian convention in 1851. The short/long Morse code is likely to continue for a number of purposes where manual reception is desirable, if not essential.

The reception by automatic printers brought in the use of equal-length codes, Baudot adopting the 5-unit binary code for the system which he invented in the 1870's—a system which marked an epoch, and which is the basis of many systems of the present day. Many codes having more than three positions have been proposed, but any that have been tried have not survived. Of the equal-length codes for general use, the choice, were it a free one, between the 5-unit binary code requiring a case-shift and the 6-unit binary code with no need of case-shift would be difficult. Several attempts have been made to introduce the 6-unit code in place of the internationally accepted 5-unit code, but it seems that the latter is now too well established.

Most long submarine cables still use the ternary cable code, but many have been changed over to 5-unit working. The 5-unit signals, although transmitted as a binary code of plus and minus voltage, must be received as ternary signals of plus, zero and minus current if speed is not to be lost. This change from binary to ternary also takes place when sending short/long Morse signals through a long cable, a vibrating relay normally being used to restore the binary signals.

Practical work on codes of recent years has been largely associated with transformations to, from or between the two existing fundamental codes, i.e. the international Morse code (short/long code or cable code) and the international 5-unit code. Examples are the sending of the Morse code over a 5-unit channel and of 5-unit code over a cable-code channel. Numerous error-detecting codes have been evolved, the favoured ones having three mark and four space elements to every character, and arranged to enable automatic transformation to be effected between them and the 5-unit code. Error detection in these codes results from the introduction of redundancy in an ordered manner.

Most of the seven speakers in the subsequent discussion were in favour of a 6-unit code from the technical point of view, but recognized that so much capital had been expended on 5-unit equipment that a reconsideration was now impracticable. One speaker, however, said that the 6-unit code has not been found superior in some long submarine circuits; experiments made in the early 1920's, when a 3-position code was to be superseded, had led to the 5-unit code as the best choice. The degree of superiority of this code over the 3-position code was reckoned as 40%, but a subsequent speaker was of the opinion that an improvement of 20–30% was as much as could normally be expected.

Both speakers noted an increasing use of the 6-unit code for particular purposes. It yields twice as many permutations, and hence twice as many characters, as the 5-unit code. The need for this augmentation may arise, for example, when a long-distance circuit is leased and the lessee stipulates that the range of available characters shall include all those found on typewriters. For similar reasons the 6-unit code is often used in America for the transmission of stock-market bulletins involving typographical peculiarities.

Reference was made to the difficulties which arise when signals are received in an emasculated form after transmission over long cables.

A speaker called attention to the valuable code introduced some 20 years ago and known to telegraph engineers as the Higgitt code. It was in effect a 7-unit code with a substantial degree of error detection, and had some features in common with the double-current cable code devised by Murray. It has been found very convenient for use with electronic code convertors.

A member with long experience of printing telegraphs spoke of the advances in technique during the past 50 years, and of the earlier pioneer work of Baudot which had laid the foundations. Even at that early stage there had, for example, been French experiments in pulse modulation with time-division channelling, but in the choice of codes there was for some years no alternatives to the Morse or the 3-position codes.

It was the opinion of this and other speakers that the technical knowledge of telegraph coding was now so complex and distributed that it could with advantage be collated and reviewed.

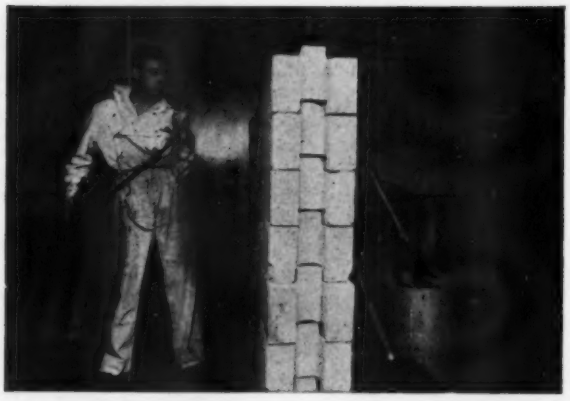
The Measurements Section discuss

RADIATION HAZARDS

On the 15th February, 1955, Mr. W. E. Harris opened a discussion on "A Services Engineer at Harwell" at a meeting of the Measurements Section. His remarks, and the subsequent discussion, are summarized below.

MR. HARRIS opened the discussion by saying that the laboratories at Harwell where research work is carried out on highly radioactive materials are called Special Buildings; in these, all maintenance and operational personnel are under the control of one engineer, who is responsible for plant operations, electrical, mechanical and building maintenance, prevention of spread of radioactivity, decontamination and cleaning, disposal of contaminated equipment, trash and liquid by-products, erection and installation of scientific equipment, supply of special services and laboratory workshops. These activities require industrial labour, which has to be protected from exposure to radiation in all its forms. A high standard of health discipline is maintained.

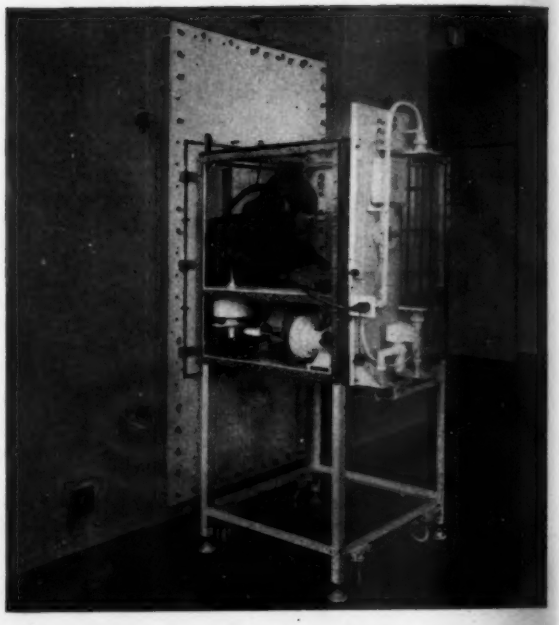
Protection from γ-rays is obtained by using shielding, e.g. lead, concrete, steel, water, etc., and work behind shielding is carried out with manipulators and other types of remote-handling appliances (Fig. 1). Vision is



1 *A demonstration of work being carried out over a concrete wall; interlocking bricks are used to prevent direct radiation through joints*

obtained by using periscopes, reflector mirrors, lead-glass windows, zinc-bromide or water windows or closed-loop television.

Emitters of α-particles in hazardous quantities are difficult to detect when airborne, and cannot be detected at all by a radiation probe. The life-time body burden of plutonium 239 is $0{\cdot}64\,\mu g$, and the maximum permissible level for a 40-hour week, if taken over the whole of a normal working life, corresponds in weight to about $10^{-4}\,\mu g$ per cubic metre of air. To measure abnormal airborne radioactivity a large volume of air is passed through a filter paper to concentrate a measurable quantity, and then time is allowed for the decay of natural radon and thoron. Work on α-particle emitters is usually done in glove boxes. Where radiation and inhalation hazards exist together shielding is used within or without a glove box (Fig. 2).



2 *A mechanic working in a glove box while dressed in a pressurized suit*

Glove boxes can be made to take anything from small analytical rigs to quite large machinery.

Electrical installations in glove boxes are, when possible, isolated in a separate compartment to mitigate risk of fire. Protection of f.h.p. motors ($\frac{1}{10}$–1 h.p.) is not simple when 100% safety is required. Small thermal cut-outs are not efficacious unless fitted into the motor windings. The electrical compartments of glove boxes are now kept filled with nitrogen to lessen fire hazards. Many of the materials used for experimental work oxidize rapidly, and with these the working sections of glove-boxes are filled with argon. Equipment and materials are passed in and out of glove boxes by using a p.v.c. sleeve secured to a glove port, and by welding items into the sleeve with a h.f. welder.

Dust carries radioactivity and helps to spread it. In Special Buildings both plenum and extract ventilation systems must be filtered; one such building at Harwell has to filter 360 000 ft^3/min, and the main filters are

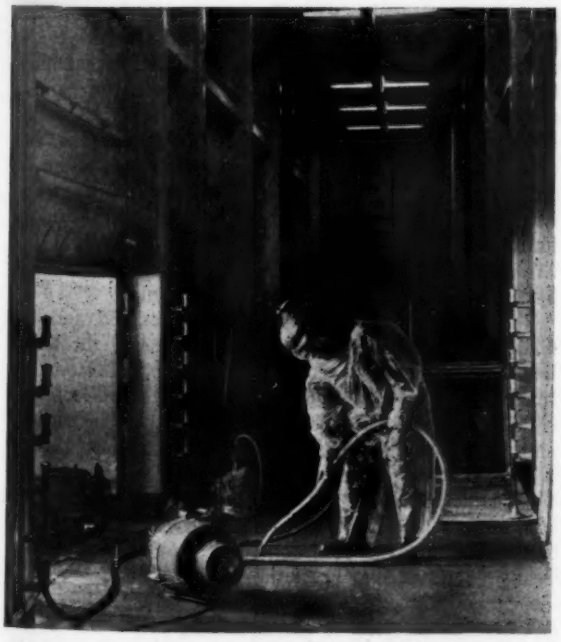
electric precipitators, supplemented by asbestos-cotton or resin-wool mechanical filters on the extraction system from compartments where a serious inhalation hazard exists. It is essential that such a system suffers no failures; this is guarded against by double feeders to the l.v. switchboard, duplicate fans and a Diesel-engine alternator for use in the event of a complete power failure. Where such large volumes of air have to be heated, it is important to reduce the flow whenever possible, to keep running costs to a minimum; for this reason a.c. commutator motors, controlled through induction regulators, are used to drive the fans.

Some areas can be entered only in special clothing resembling diving suits, and this necessitates the provision of chemical and fresh-water showers, intercommunication control, breathing air lines with flow meters and valves and facilities for decontaminating equipment (Fig. 3).

Serious loss of effective manpower is caused directly through working with radioactive materials. Losses due to monitoring and other health precautions in one Special Building amount to 1·64 hours/man/day, but it must be understood that this figure refers to an experimental establishment and will be considerably less for an industrial establishment carrying out planned processes.

In the discussion which followed there were several references to the disposal of contaminated material and equipment. Incineration is adequate for some articles which are lightly contaminated, and p.v.c. shrouds, which are used for temporary protection of apparatus, can be decontaminated merely by laundering.

Equipment which has been seriously affected is put into plastic bags, bulky pieces being cut up if necessary. The bags are put into drums and the remaining space is filled with concrete. The nature and degree of activity of the contents of the drums are certified, and they are then jettisoned in mid-Atlantic. Liquids for disposal are put into lead flasks. By flocculation or other appropriate treatment the harmful substances are reduced to a sludge, which can then be discarded by the methods accepted for solid materials. Mr. Harris observed that not all material is condemned because of its radioactivity, for some is useful to industry for this very reason.



3 *Man in pressurized suit using a special vacuum cleaner fitted with resin-wool filters*

Noting the general use of intercommunication sets in Special Buildings, a speaker asked how such equipment was preserved from contamination. Mr. Harris replied that a shrouding of polyvinyl chloride could always be used, but generally the equipment could be accommodated in a "clean" area away from danger. Siting at a distance was also the practice for other reasons, e.g. commutating machines which might interfere with sensitive instruments.

One speaker suggested that the level of radioactivity in Special Buildings could be controlled partly by more general use of glove boxes. The quantity of air to be treated and circulated, and the consequent loss of heat to be made good, might then be reduced with great economy. To the same end, each fume cupboard might have its own exhaust system, with individual control. Likewise, the purifying and recirculation of otherwise waste water was commended.

A speaker with experience of the factories of the United Kingdom Atomic Energy Authority, as distinct from the laboratories, said that there the problem of precautions was much simplified because the processes which would be carried out were known at the time of building and were taken into account in the design. Moreover, experience had shown that the hazards are less severe than had been expected. This was also the opinion of a speaker from the laboratories, who considered that some of the safeguards, and consequent loss of time, may be reduced as experience is accumulated.

On matters of detail, the factory view was that 50 volts was preferable to 250 volts for portable equipment and obviated exacting inspections of earth-continuity conductors. A point of instrument design was also mentioned: frequently the sensing element, which is to be exposed to radioactivity, is of intricate and costly design. An expendable element of simple form could be more readily decontaminated, or if necessary, discarded.

When valuable instruments, e.g. radiation monitors, have to be taken into highly radioactive areas, thin Perspex is placed over the dials to act as windows and the whole is then sprayed with a robust packaging coat, which is next cut and stripped from the centre of the dial windows, leaving them clear. Packaging coats strip cleanly when it is desired to remove them for servicing. At the moment, only one make of packaging coat which will not attack Perspex is known.

HOME EVENTS

LONDON

RADIO AND MEASUREMENTS SECTIONS

Transistors Again

Transistors now rival colour television as a draw for a Radio Section Meeting and for the enthusiasm of the discussion. The joint meeting of the Radio and Measurements Sections on the 11th May, 1955, proved no exception to this generalization, and many of the points raised in the two papers on other semi-conductor devices were of equal interest to the transistor specialists.

The five papers read were as follows: *Noise in Silicon Microwave Diodes*, by Mr. G. R. Nicoll. *Measurements of Junction-Transistor Noise in the Frequency Range 7–50 kc/s*, by Mr. W. L. Stephenson. *A Germanium Diffused-Junction Photo-Electric Cell*, by Mr. J. M. Waddell, Dr. S. E. Mayer and Mr. S. Kaye. *Transistor Power Amplifiers*, by Mr. R. A. Hilbourne, and Mr. D. D. Jones. *Transistor D.C. Convertors*, by Mr. L. H. Light and Mrs. Prudence M. Hooker.

Naturally, it was difficult to do full justice to all these papers at one meeting but nevertheless discussion warranted the joint presentation, since points from one paper were often referred to in the discussion of another.

Mr. Nicoll's paper is largely concerned with establishing the role of shot and flicker noise in silicon diodes and the extent to which the calculated values of shot noise agree with the measured values. His findings are that flicker noise may be greater than shot noise at frequencies up to at least 45 Mc/s, and in diodes with low flicker noise good agreement between theory and measured shot noise is obtained. Perhaps as a sign of the times, the audience showed no surprise that measurements could also be made reliably at 40 000 Mc/s, where the author's findings indicate that flicker noise is not important.

The paper by Mr. Stephenson, besides dealing with the measuring technique and the equivalent circuits for a transistor with a noise source, includes a number of experimental results showing the dependence of noise factor on operating conditions. Some of his conclusions led to a lively discussion.

The paper by Mr. Waddell, Dr. Mayer and Mr. Kay describes the main constructional features of their *p-n* junction photo-diode, of which the advantages appear to be a large output for its very small size. They have found that it responds to excitation at a somewhat longer wavelength than their theory predicts and that it has a much lower noise level than point-contact junctions.

Little discussion has so far taken place on the relative merits of Class A or Class B power amplifiers using transistors and the alternative methods of using the transistors themselves. Mr. Hilbourne and Mr. Jones have set out to make good this gap; in particular they compare the common-base, common-emitter and common-collector push-pull circuits, and show that in assessing their merits the power required to drive them should also be considered. They show also that the variation of current gain, over the range of emitter currents used, can cause considerable distortion, and demonstrate that though very high efficiency and low battery voltages are very attractive, the distortion from this source and from cross-over distortion can be very great unless care is taken.

The paper by Mr. Light and Mrs. Hooker is of great interest to those seeking a simple way of developing power of a few watts at voltages up to some hundreds of volts from a low-voltage battery supply. After dealing with the basic circuit the authors examine all the practical aspects of the design of the auxiliary components and the methods of stabilizing the output against load or input voltage variations.

The lively discussion that followed the introductions to the papers showed that it was desirable not only to be able to appreciate the physical phenomena taking place in the semi-conductor but also to be a practical engineer, and many very useful suggestions were put forward in both these fields.

Dr. J. R. Tillman and Mr. J. W. R. Griffiths were in favour of the equivalent noise generator being in the output of the circuit to correspond more closely with the physical source of noise. Dr. J. Evans, Mr. Griffiths and Mr. F. F. Roberts all disagreed with the statement that noise was independent of collector voltage and some suggestions were made to explain their findings. Dr. Tillman suggested that the long-wavelength response of the germanium photocell could be explained by the optical transmission and properties of germanium, and Mr. Roberts suggested that the short-wavelength response could be explained by the optical absorption properties. Dr. Evans suggested that the d.c. convertor might be improved by the use of high-resistance germanium, and Mr. E. H. Cooke-Yarborough and Dr. G. B. B. Chaplin added to the ideas on the design of circuits.

Transistor symbols were keenly discussed and Dr. Chaplin's recommendations with the use of the blackboard appeared to receive some support from the meeting, in spite of doubts regarding their acceptance by our American friends. Whether positive or negative should be shown uppermost in a diagram also became a bone of contention.

Considerable interest was shown in the paper on power amplifiers. Mr. J. N. Barry and Mr. E. Wolfendale did not agree that the common-collector arrangement was really so attractive when the power requirements and design of the drive stage are considered, and Mr. Wolfendale referred to transistors in which the current gain is maintained with currents of up to 1 amp. Mr. T. W. Sheppard also suggested that at high ambient

temperatures the possibility of thermal instability, as with the germanium photocell, had to be borne in mind.

By the time eleven people had contributed to the discussion it was approaching eight o'clock, and the authors were able to reply to only a few of the points raised. The meeting closed with a vote of thanks to the authors by Mr. W. Bamford, Vice-Chairman of the Measurements Section. N. R. B.

SUPPLY SECTION

A Capital Supply

Considering that the weather indicated the approach of summer, the attendance at the meeting of the Section on the 18th May, 1955, was extremely good and indicated the great interest in the paper entitled *The Supply of Electricity in the London Area*, which was presented by Mr. D. B. Irving. The meeting, the last of the Session, was presided over by Mr. J. D. Peattie. A digest of the paper appears on page 526.

The detailed manner in which the history of the supply is described in the paper clearly indicates the enthusiasm of the author for this aspect and it incidentally drew from the meeting further details of some value.

High-lights in the author's résumé were a schedule showing the dates of the original orders sanctioning the supply of electricity and the actual initiation of the supply by various companies; and a load flow diagram showing the destinations of the supply. With regard to the schedule, it is noteworthy that some supply companies actually gave a supply before receiving the necessary powers, several districts in the early days were left without supply and in some districts more than one undertaking was sanctioned, generally one for a.c. and one for d.c. supply.

An additional item was the exhibition of a short film illustrating the spiking of a cable to ensure that it is dead before work upon it is carried out. The 22 kV cable shown required procedure reminiscent of the best H-bomb preparation technique, but the final spiking produced a very moderate transient.

Mr. Forbes Jackson, who opened the discussion, was very glad to see the paper read before The Institution, because after 1947 he had felt that the affairs of the supply industry might disappear behind a kind of a curtain. Amongst his historical, technical and human reminiscences, which were very relevant, he mentioned a 1914 report by the late Charles Merz, relating to the London Electricity Supply, in which Merz prophetically stated that the remedy for eliminating the prevailing confusion was to create a new amalgamated undertaking for the whole supply. Mr. Jackson's references to his negotiations for the housing of 500 kVA supply transformers by people or bodies who required only 100 kVA were both edifying and educational.

Amongst the other eight contributors Mr. J. W. Leach, a former chief engineer of the London Electricity Board, pleaded for some information of a similar kind from other areas, and dealt also with solid and interconnected systems and with the administration plan for training personnel for management duties. He suggested that a life of 50 years was reasonable for cable, switchgear and transformers in order to reduce interest and sinking-fund charges. Mr. B. Donkin asked if it was possible to express a preference for any one type of gas-pressure cable and raised the question of fault power in kVA at consumers' terminals in relation to the consumers' protector devices. Mr. L. H. Welch said that although the network which existed was extremely complicated it was perhaps not so much so as the tariff structure; he also dealt briefly with the history of the d.c. system. Mr. H. V. Pugh, after giving certain figures regarding the capacity of the divisional power stations, suggested that generating plant which was 50 years old might be used to deal with the peak loads; with a load factor of 5% such plant could be expected to go on operating indefinitely. It could be kept for dealing with occasional megawatts and not for producing megawatt-hours.

Mr. R. R. H. Taylor, also of the London Division, emphasized the good relations between the Division and the Board and the joint planning that was carried out. Mr. H. I. Kenner suggested the synthesis of the two methods of h.v. distribution, interleaved and standard, combining the transforming economy of the one with the flexibility and cable economy of the other.

In his reply the author dealt with the majority of the points raised and added some further information. He made the point that it was impossible to plan the future without knowing the past. He also dealt with the elimination of direct current from the system and with the energy and burning out of faults. Mr. J. W. Leach accepted the author's invitation to answer a question on short-circuits on the London system.

Mr. J. D. Peattie, in proposing a vote of thanks to the author from the chair, expressed the feeling of all present when he said that they had had a very happy evening and that the paper was most opportune in marking a stage of evolution since Vesting Date. E. L. D.

HULL

DISTRICT MEETING

The fourth District Meeting was held on the 24th February, 1955, with Mr. W. S. Milner in the chair. Mr. M. J. L. Pulling read the paper entitled *Technical Arrangements for the Sound and Television Broadcasts of the Coronation Ceremonies on the 2nd June, 1953*, of which he is joint author with Mr. W. S. Proctor and Mr. F. Williams. This most informative paper was very well presented and profusely illustrated with lantern slides, and the speaker included as a fitting climax a sound film of two forms of tele-recording. A lively discussion in which seven local members took part followed and Mr. Harris proposed a vote of thanks to the speaker.

The final District Meeting took place on the 31st

March, 1955, when Mr. F. H. S. Brown read his paper entitled *Some Design Features of the Semi-Outdoor Power Station at Ince* before 22 members and guests. The interest of guests from the local power station was soon apparent and several joined in the discussion which followed. Mr. W. S. Milner from the chair expressed thanks to Mr. Brown. J. L.

STOKE

NORTH STAFFORDSHIRE SUB-CENTRE

At the Annual General Meeting on the 3rd May, 1955, the Chairman, Mr. J. M. Ferguson, reported the results of another successful year. There was a substantial increase in membership and the meetings continued to be well attended. This was gratifying, since the Committee had been careful to choose papers of general and varied interest to enable members to keep in touch with developments outside their own fields. The first District Meeting at Burton had been very successful and many requests had been received for another meeting there next year.

The Chairman referred with regret to the resignation of Col. C. E. Calveley, immediate Past-Chairman, on taking up new duties in London, and of Mr. W. G. Friggens, the Secretary, on his transfer to Bradford. Although Mr. Friggens had been unable to complete his term of office, he had fully maintained the tradition of hard work set up by his predecessors.

As a result of the ballot, Mr. R. H. Bannister, Mr. W. E. Darby, Mr. J. L. Hewitt and Mr. R. W. Palmer were elected to serve on the Committee. Mr. Ferguson welcomed these new members and also expressed thanks to the retiring members, Mr. A. R. Buttrey and Professor F. A. Vick, for their valuable services to the Committee.

At the Ordinary Meeting which followed, Mr. Ferguson introduced Mr. E. Edmundson, Chairman of the twin Sub-Centre at Rugby, and invited him to read his paper on *Electrical and Magnetic Measurements in an Electrical Engineering Factory*. The paper describes the application of the negative-feedback amplifier and of a high-speed polarized relay, capable of 500 operations per second, to a wide range of practical measurements, many of which are difficult by ordinary methods; the measurement of low power and of power at low voltages are examples. A keen discussion followed and all points were ably dealt with by the author.

In proposing a vote of thanks, Mr. A. T. Chadwick said the paper was of equal interest to both manufacturers and users, since accurate measurement forms the basis of proof of guarantees, which are of prime importance to industry. The method by which whole sheets of transformer steel were tested was especially valuable and should assist in obtaining steels of much more uniform quality, which would greatly help the designer. L. G.

YORKSHIRE

NORTH MIDLAND CENTRE

The eighth Ordinary Meeting, on the 15th March, 1955, was far from being ordinary. In the first place, it was held at the Technical College, Bradford, and secondly, no less than 350 members and guests were present when the Chairman, Mr. W. A. Crocker, after welcoming one new Corporate Member, called on Dr. G. N. Patchett, to give his lecture entitled *Colour Television*. This was reinforced by a display of demonstration apparatus and Dr. Patchett held the meeting enthralled with his brilliant exposition of this extremely interesting subject. The discussion, opened by Mr. D. Westwood, covered a wide variety of questions which were most capably answered by the author. The large gathering of members and friends was therefore completely in accord when the Chairman called for a vote of thanks, and it was given with whole-hearted applause.

On the 18th March, 1955, the Centre held its Annual Dinner-Dance at the Cairn Hydro, Harrogate—a most enjoyable function attended by 320 members and their guests. Everyone expressed appreciation of the excellence of the arrangements and the new venue was declared a complete success. The appeal for the Benevolent Fund made by the Local Hon. Treasurer, Mr. J. G. Craven, realized £150.

Chocolate and the Channel

The ninth Ordinary Meeting, on April 5th, at the Royal Station Hotel, York, had been preceded, through the kindness of Mr. Noel G. Terry and Mr. E. Clayton, by a most interesting visit to the works of J. Terry and Sons. At the evening session, attended by 110 members and guests, the Chairman, after welcoming one new Corporate Member, introduced Mr. D. P. Sayers, who read the paper on *The Possibilities of a Cross-Channel Power Link between the British and French Supply Systems*. This was followed by a colour film of the trials which had taken place in the Channel, and both the film and the paper were very well received.

The discussion, which ranged over both the economic and technical aspects of the subject, was opened by Mr. H. C. Ogden and continued by seven other members. The Chairman thanked Mr. Sayers for his excellent presentation and for a most interesting and instructive evening.

A Permeance of Past-Chairmen

The year's work was brought to a formal close at the Annual General Meeting in Leeds on May 3rd, when it was revealed that, because they were taking up appointments outside its boundary, the Centre was to lose both the Chairman, Mr. W. A. Crocker, and the Secretary, Mr. H. G. Harlow. Gratitude and appreciation of Mr. Harlow's valued service were expressed by Mr. J. R. Rylands, who went on to give a welcome to Mr. H. Carr, the newly appointed Secretary. The Meeting included

a most pleasing ceremony when thirteen Past-Chairmen and two Past-Secretaries were personally presented with copies of *The History of The Institution*. Mr. J. N. Waite, as senior Past-Chairman (1933–34), replied on behalf of Mr. E. L. E. Wheatcroft (1934–35), Mr. S. R. Siviour (1936–37), Mr. J. G. Craven (1937–38), Mr. J. W. Atkinson (1938–39), Mr. W. F. C. Cooper (1942–43), Mr. W. T. J. Atkins (1943–44), Mr. E. Lunn (1944–45), Mr. A. G. Connell (1946–47), Mr. J. R. Rylands (1949–50), Mr. W. F. Smith (1950–51), Dr. E. C. Walton (1951–52), Mr. H. S. Moody (1952–53), and of the Past-Secretaries Mr. K. C. Coop and Mr. F. W. Fletcher. He spoke of the great pleasure it gave them to receive their invitations to this ceremony, and told with what delight they had accepted and with what pride they would cherish their books. They had travelled long distances to be present, but it was delightful to see old colleagues again and they all wished continued success to the North Midland Centre.

Talking on the Map and . . .

Members then proceeded in accordance with custom to hear a non-technical lecture, this year given by Professor H. Orton and entitled *The New Survey of English Dialects*. Professor Orton's researches in this sphere have led to a fascinating thesis, and the historical implications which can be accurately drawn solely from the evidence of dialect, pronunciation and grammar, were news to many of his audience. He told of a linguistic atlas which was being drawn up and mentioned field workers who fill in questionaries on visits to agricultural communities.

Mr. F. Barrell and Mr. W. K. Fleming showed quite a grasp of the subject in proposing and seconding a vote of thanks to Professor Orton. The Chairman reported that Mr. J. G. Craven's appeal for the Benevolent Fund had realized over £14.

. . . Giving on the Links

Coming as it does after the Annual General Meeting, the Golf Competition, held this year on the 24th May, 1955, may be thought to be an anti-climax, but the 60 or more members who took part will testify to the contrary. The weather was reasonably kind and the day's sport was thoroughly enjoyed; rather more than £125 will therefore go to the Benevolent Fund. Special thanks are due to Mr. F. Smith who spares no effort in the organization of this function year by year. It is also right to recall that Mr. R. Horlock has given much time in former years as Treasurer of the Golf Competition as well as Treasurer of the Centre. It is understood that before he left this country to take up a position in Canada he raised £1 000 from Golf Competitions for the Benevolent Fund.

NORTH MIDLAND UTILIZATION GROUP

At the fourth meeting, held on the 22nd February, 1955, and attended by 46 members and guests, an informal discussion on *Power Factor and Methods of Correction* was opened by Mr. W. A. Brecknell, who dealt with static capacitors, and continued by Mr. P. Huggins, who confined his remarks to rotating plant. Many other members joined in and at the close the Chairman, Mr. N. S. Goddard, expressed the thanks of all present to those who had contributed to an interesting evening.

At the fifth meeting, held on the 22nd March, 1955, with 46 members present, great interest was aroused by two Students' papers. First Mr. G. Streets read his paper entitled *The History of Electric Street Traction*. This paper deals comprehensively with the legislation and other difficulties which hindered the development of tramways, and strongly presses the advantages of modern tramcars while at the same time admitting and deploring the serious decline in this form of transport to-day. A short discussion was opened by Mr. J. R. Hanchet and three other members followed him. Secondly, Mr. L. N. Hulley read his paper on *The Utilization of Electric Power in Rhodesian Copper Mines* which proved a most interesting account of the author's experiences and impressions, together with an excellent description of the plant at the Mufulira mine. Questions were asked afterwards by Mr. Gascoigne and two other members, and the author replied.

NORTH MIDLAND EDUCATION DISCUSSION CIRCLE

The Circle continues to function satisfactorily. A small but sincere band have held four Discussion Meetings during the session on the following subjects: *The New I.E.E. Examination Regulations* (9th November, 1954—opened by Dr. E. C. Walton); *The Place of Electrical Network Theory in Electrical Courses* (14th December, 1954—opened by Dr. G. S. Brayshaw); *The Scope of Protection in H.N.C. Syllabuses* (25th January, 1955—opened by Mr. D. Fawcett) and *j-Notation* and *Graphical Methods* (15th February, 1955—opened by Mr. R. A. H. Sutcliffe and Mr. T. R. Lupton).

NORTH MIDLAND STUDENTS' SECTION

The Section continues to be a success, and new members are obviously enjoying the meetings.

On the 8th February, 1955, at Bradford, Mr. P. N. Bentley read his paper on *Engineering Drawing-Office Practice* which deals fully with this complex subject, and the discussion revealed a lively interest.

At Leeds, on the 8th March, 1955, the Section entertained Dr. E. C. Cherry, who read his paper on *Communication of Information—Human, Animal and Machine*. This very involved subject captured and held a large audience.

The last meeting of the session was held on the 26th April, 1955, when Mr. D. Pitts read his paper on *Electric Contracting* and illustrated it by excellent coloured lantern slides of his own making.

Five visits to works have taken place during the session, and a Summer outing in the form of a Motor Rally has been arranged. J. L.

NEWS *from abroad*

BASRAH

IRAQ AND PERSIAN GULF JOINT OVERSEA GROUP

The Annual General Meeting of the Group was held in Basrah on the 15th April, 1955, with Mr. R. C. Kelt in the chair. There was an excellent attendance of members from Kuwait, Kirkuk, Baghdad and Basrah. The Chairman gave an interesting report on the year's activities, which have been most successful. He stated that it was hoped to arrange meetings in Teheran, Bahrein and Kirkuk during the coming year. After the meeting an account of the oil terminal and port dredging depot at Fao was given by Mr. R. C. Cutler of the Basrah Petroleum Co. On the following day members visited Fao itself and saw the dredging and marine depots and the oil-terminal jetties and installations. J. M. M.

COLOMBO

CEYLON OVERSEA BRANCH

Address by the Vice-Chairman

The Nineteenth Annual General Meeting of the Ceylon Oversea Branch was held in Colombo on the 28th March, 1955. After the adoption of the Accounts and the election of Officers and Committee the Vice-Chairman, Mr. G. D. Somasundaram (in the absence of the new Chairman, Mr. E. C. Fernando, who was in New Zealand), gave an address to the meeting, in the course of which he said:

"I propose to speak on *Electrical Development in this Island*. It is a subject in which I have been interested for over 20 years—a sufficiently long period to form ideas—and I wish to put some of those ideas before you and suggest a few ways in which we can help the electrical development of our country.

"Ceylon is an agricultural country, the main products (tea, rubber and coconut) accounting for over 96% of her exports. To produce and process these commodities for the world markets we require an enormous amount of power, the tea industry alone needing 30 000 h.p. for motive power and 60–80 MW for withering and drying. The rubber and coconut industries use about 45 000 h.p. but a good part of the produce of the coconut palm is now sent out in a semi-finished state, so there is room for more consumption here. There are other industrial loads which will develop as cheap power becomes available. Taking into consideration the domestic field also, I suggest that we have a total potential consumption of 8 000 million kWh per annum, which would bring the consumption *per capita* to 1 000 kWh per annum. At present the figure is well under 18. The February *Journal* quoted very high figures of consumption in the West Indies, and elsewhere there are several countries where the consumption is over 1 000 kWh per annum.

"Ceylon imports annually between 40 and 50 million rupees' worth of fuel. But Nature, who denied us coal and other fuel, has been bounteous in providing us with abundant sources of water power which can be economically developed. The late Mr. D. J. Wimalasurendra estimated in 1918 that the six largest sources will yield 370 MW, and Turner's 'Handbook of Ceylon' gave 700 000 h.p. as the output of 37 sources. Our largest source, the Kehelgamu Oya, is in course of development, and it is time we carried out detailed investigations into the other major sources.

"It is also incumbent on us to take adequate measures to safeguard our national wealth in water power. There is not at present sufficient legislation to control the tapping of our water sources for private use and we may find later, when we build our dams to make our reservoirs, that the flow of water is restricted and compensation is demanded for loss of water rights.

"Suggestions for the creation of a central body entrusted with the overall supervision of the electricity supply industry have recently been made, and indeed have been made from time to time in the past 30 years. If such suggestions mature the opportunity should be taken to remove some of the unsatisfactory features of the present set-up, for example the provision whereby the wholesaler acts as the retailer and also as the electrical inspector; the inspector should not be the arbiter in his own cause and have the final decision in law.

"In developing our electricity industry our aim should be not only to produce an abundant supply of electricity but to produce it cheaply. Our power-station engineers keep careful records and maintain charts giving the thermal efficiency, cost per unit generated, etc., and by this and other means have developed their part of the business to a high standard of efficiency. But can we say the same of transmission and distribution? In a particular undertaking the cost of transmission per unit rose steadily in five years from 0·45 to 1·35 cents. These figures, which are exclusive of capital charges and distribution costs, indicate that transmission costs per unit had trebled in a period during which the units sold had doubled.

"Extensions in one area may be more desirable than in another, even when the two areas have equal potential loads. For instance, the tea load to which I have referred is so situated that 25% of it lies within a distance of 16 miles of the hydro-electric station and it would be possible to secure this load without taxing the already overloaded main transmission line.

"Even in our largest cities less than one third of the houses have taken a supply for lighting. A still smaller proportion use electricity for other purposes as well.

In the rural areas the position is still worse. In order to develop our electrical load we must first extend our lines into the rural areas and tap whatever load there is, and, secondly, endeavour in the areas which are already electrified to get more consumers and to sell more to existing consumers. The fact that we do not produce steel may justify our importing wood poles, which have already proved satisfactory. But we should also have a thorough investigation into the possibilities of using locally grown timber, into which we need much more research. We can simplify rural lines and standardize equipment without seriously affecting reliability. A high percentage of our present interruptions are deliberate cuts for purposes of maintenance, but if our lines were so planned and our maintenance so organized that these interruptions were reduced to the minimum there should be no serious objection to a slight increase in the accidental interruptions.

"Lastly, let us as engineers develop goodwill with our consumers and conduct ourselves in such a way as to win the confidence of the public we serve. Every satisfied consumer is a potential canvasser for the undertaking. Let us therefore have as many canvassers as we possibly can."

NEAR EAST

Further Talks on Telecommunication

In pursuit of a talk on telecommunication given in February by the Near East Representative of Council (see May *Journal*, page 314), at the American University in Beirut, Lebanon, two further speakers gave talks on aspects of this subject at the same place on the 20th May, 1955.

Mr. H. A. Odell gave a short lecture on *Telephone Transmission* illustrated by slides and tape recordings, and a Lebanese colleague, Mr. Bishara Y. Nassar, described *Automatic Telephone Exchange Switching* by the Strowger or step-by-step system. There was a good attendance of members of the public, university staff and students.

Mr. Odell's lecture was an attempt to cover the whole field of the telephone transmission engineer's work. He described the duties of a transmission engineering group in a communications administration as the planning and maintaining of telephone and telegraph circuits throughout a system, in such a way that contact between stations is by way of circuits which conform entirely to acceptable standards of loudness, freedom from noise, intelligibility and freedom from interference into or from other circuits. This involves planning, installation and maintenance of the instruments, local lines, exchanges, trunk switchboards, carrier equipment or audio interconnecting equipment between trunk switchboards, and, where there is a teleprinter network, special local and trunk circuits, switchboards and terminal equipment. The switching side of telephone engineering was omitted from the lecture because, as Mr. Odell said, it is usually "somewhat separate."

After a reference to the distinction between radio and line transmission—a distinction now becoming more difficult since both kinds of link may have a common termination and their frequency ranges are no longer exclusive—Mr. Odell stated the basic requirements and described a good telephone circuit as capable of transmitting all frequencies from 300 to 3 400 c/s, but showed that a compromise between cost and fidelity is necessary in providing the lines and equipment for commercial speech. Music transmission needs a band of 100–10 000 c/s and a picture circuit must transmit a much wider one. Television bandwidths are in the megacycle range. The coaxial-cable carrier systems, which give hundreds of speech circuits on one pair of conductors, also use frequencies transmitted to line in the megacycle range.

Mr. Odell explained the attenuation inherent in a physical line and how this once serious limitation to long-distance communication is overcome nowadays by the insertion of repeaters. He also described the steps taken to eliminate or reduce cross-talk between circuits in multi-pair cables. When carrier methods on cables were introduced, not only the provision of additional channels became cheaper, but mutual interference was eliminated and speech equality improved as a result of the necessary use of terminal amplifiers. The economic advantage compared with an overhead line is felt on all routes longer than about 20 miles.

The lecturer very properly included an enlightening reference to the I.T.U. and to the C.C.I.F., C.C.I.T. and C.C.I.R., without whose deliberations international communications might still be very limited in range and quality. He stressed the importance of impedance matching between a line and the equipment associated with it, and mentioned the modern method of locating line faults by an oscillograph and a pulse generator, with which an accuracy of $\pm\frac{1}{4}$ mile is often possible.

OVERSEA ATTENDANCE REGISTER

During the period 1st June to 30th June, 1955, the following members called at the Institution Building and signed the Attendance Register of Oversea Members:

BAKER, W. E. (Hong Kong).
BARRS, H. H. (Christchurch).
BATE, H. (Ndola, N. Rhodesia).
BROD, E., Dipl.Ing. (Salisbury).
BUSS, D. A. (Lagos).
CAMERON, J. S., B.Sc. (Montreal).
CHANDRA, B. K. (Calcutta).
DAVIES, C. S. (Freetown).
DRAKE, H. H. (Burnpur, India).
FELIX-SMITH, L. E. (Auckland).
HARDMAN, J. (Zanzibar).
LEVITAN, P. M. (Nairobi).
LINDE, L. J. (Milwaukee).
MENDIS, T. W. (Colombo).
OLVER, G. C. (Toronto).
PAPAGIORGIS, D. A. (Nicosia).
TEMPLETON, J., B.Sc. (Christchurch).
WILSON, J. (Melbourne).

Electricity in London

A DIGEST OF A SUPPLY SECTION PAPER (No. 1748) ENTITLED "THE SUPPLY OF ELECTRICITY IN THE LONDON AREA," BY D. B. IRVING, B.SC., MEMBER. THE FULL PAPER WAS PUBLISHED SEPARATELY IN NOVEMBER, 1954, AND IT WILL BE REPUBLISHED IN PART A OF THE PROCEEDINGS.

THIS IS A SURVEY PAPER giving a glimpse of the confused background of electricity supply in the London Area over the past half-century and making reference to some of the steps taken since nationalization to plan and conduct the activity in a comprehensive manner. The history of organized supplies goes back well into the last century, and Figs. 1 and 2 show examples of early installations which gave long service.

The Area considered in the paper is that now supplied by the London Electricity Board, 257 square miles in extent, in which there were, prior to 1948, 30 municipal electricity undertakings and 11 company undertakings. Twenty municipalities did not operate electricity departments, and in some parts there existed duplication of supply powers.

Movements towards rationalization of conditions in parts of the Area occurred from time to time, either as a result of legislation or technical advances. An amalgamation of six West End companies in 1937 was an important step in the rationalization of supply administration and systems within the six square miles of that part of the Area.

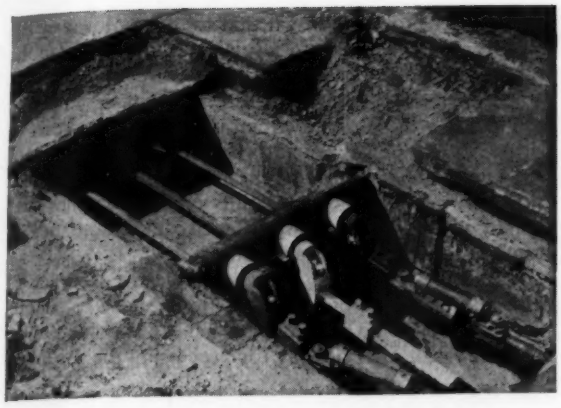
In 1947 the Act was passed under which responsibility for generation passed to the British Electricity Authority. The £72 000 000 of transmission and distribution assets of the former municipal and company undertakings in London became vested in the London Electricity Board.

The complex pattern of the 40 distribution systems inherited by the Board included single-phase, 2-phase, 3-phase and d.c. supplies, with no fewer than 20 distinct voltages of utilization between 100 and 500 volts. High-voltage systems operating at 18 different voltages between 1 and 11 kV were also present.

For the transmission of supplies in bulk there were cable circuits operating at 22, 33 and 66 kV, and among these were to be found the more modern types of oil-filled and gas-pressure cable. The complexity of these underground circuits is shown in Fig. 3.

With the renewed impetus in the growth of load after the 1939–45 War, the need for reinforcement of bulk supplies at many points became extremely urgent. This would not admit of the delay inherent in the detailed assessment of the whole London position and the subsequent preparation of the Board's long-term plans for the Area. It was, therefore, necessary to plan and construct the more urgently needed reinforcements concurrently with the formation of long-term plans having as their objective the provision of adequate circuit capacities with the minimum of bulk-supply transmission within the Area. All technical considerations, however, are governed by the need to utilize to the full—within

1 *The first 10 kV substation in the world, showing map of overhead 2·4 kV mains in 1887 (Cockspur Street, Trafalgar Square)*



2 *Crompton culvert, d.c. distribution main (1886–1954)*

economic limits—the mosaic of transmission equipment inherited at Vesting Date.

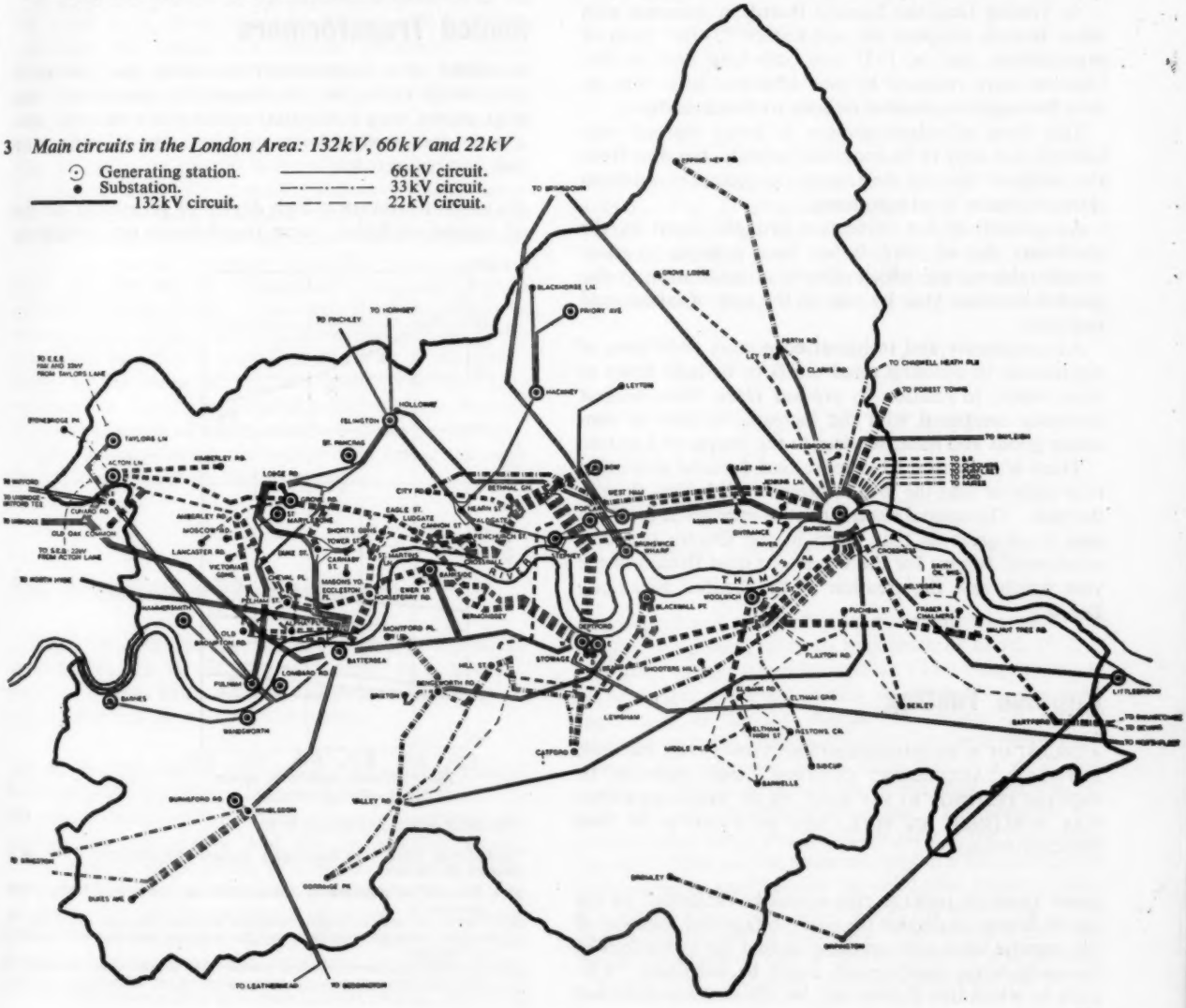
There are seven 66kV substations having a total installed transformer capacity of 500 000kVA, and 72 main substations, supplied at 33 or 22kV, the installed capacity of the transformers being 2 263 940kVA.

The number of local substation and transformer chambers, where voltages of 11 and 6·6kV are reduced to supply medium- and low-voltage networks, is 7 128, with an installed transformer capacity of 3 535 638kVA.

The urgency of the need for reinforcement was responsible for a decision to regrade the h.v. cables in ten Districts from 6·6 to 11kV. Some gloomy forebodings concerning the vulnerability of joints have so far proved to be unfounded.

The problem of standardization of m.v. systems is a very large one and, notwithstanding the work which has

3 *Main circuits in the London Area: 132kV, 66kV and 22kV*



been undertaken since Vesting Date, there remain nearly 800 000 consumers connected to non-standard systems in the Area. Change-over policy is governed by restrictions on capital expenditure, and attention is necessarily focused upon overloaded non-standard systems.

In parts of Central London the load density, already in excess of 100 mW per square mile, is expected to approach 200 mW per square mile within the next 15 years. Extended application is being made of interconnected low-voltage systems with "interleaved" 500 kVA distribution transformers.

Engineering Headquarters have direct responsibility for all work associated with the 22–66 kV transmission systems and bulk-supply points, while Sub-Area and District staffs, under the guidance of Headquarters, have responsibility for the 11 kV and lower-voltage distribution systems.

At Vesting Date the London Board, in common with other Boards, adopted the well-known "3-tier" form of organization, but in 1953 one Sub-Area and its five Districts were replaced by two Districts, each with its own Manager responsible directly to Headquarters.

This form of administration is being studied with interest, not only in its economic aspects, but also from the point of view of the impact on consumer relationships of greater local autonomy.

As a result of the unification brought about by the Electricity Act of 1947, it has been possible to effect considerable savings which offset in no small measure the general increases year by year in the cost of labour and materials.

Administrative and technical economies have been of significance in enabling retail tariffs to be held down to rates which, in relation to pre-war rates, show modest increases compared with the increases in cost of consumer goods and other services to the people of London.

There is no reason to suppose that demand saturation is in sight or that the rate of growth will be less than in the past. The annual electricity consumption in the Area now is as great as that given in the Electricity Commissioners' Return for the whole of Great Britain in the year which saw the creation of the Central Electricity Board.

Impulse Testing

A DIGEST OF A MEASUREMENTS SECTION PAPER (No. 1839) ENTITLED "AUTOMATIC CONTROL AND DISPLAY IN IMPULSE TESTING," BY R. F. SAXE, PH.D. THE FULL PAPER WAS PUBLISHED IN MAY, 1955, IN PART B OF THE PROCEEDINGS.

MANY TYPES OF IMPULSE TEST would be facilitated by the use of devices to display the peak voltage and duration of the impulse wave without delay so that the limitations of the cathode-ray oscillograph could be overcome. Circuits by which this display may be achieved are described in the paper and it is shown that the breakdown of the test object may be made to give a clear indication on the meter monitoring the duration of the wave.

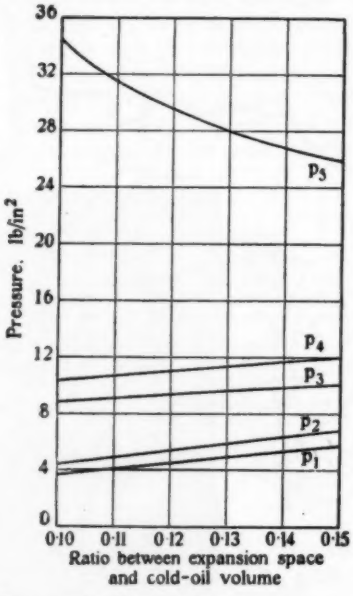
The operation of the impulse test equipment may be facilitated by the use of a circuit which may be preset to trigger the impulse generator at a definite value of charging voltage. Further, the use of relays associated with the display and triggering circuits enables any desired test sequence to be carried out automatically. Representative examples are quoted.

The above-mentioned circuits enable an accuracy of about $\pm 2\%$ to be obtained, and are intended to supplement oscillographic recording, which can provide a more accurate result after a delay for processing the recording film.

Sealed Transformers

A DIGEST OF A SUPPLY SECTION PAPER (No. 1674) WITH THE ABOVE TITLE, BY E. B. FRANKLIN, ASSOCIATE. THE FULL PAPER WAS PUBLISHED SEPARATELY IN JUNE, 1954, AND IT WAS REPUBLISHED IN JUNE, 1955, IN PART A OF THE PROCEEDINGS.

IN ORDER TO OBTAIN a high degree of protection for the oil against oxidation, some transformers are completely



Pressures in the expansion space

Transformer filled with thoroughly degassed oil and sealed with air at once at 14·7 lb/in².

p_5 = Internal gas pressure at full temperature (calculated from simple gas laws).
p_4 = As p_5, but with additional account taken of gas solution in the oil.
p_3 = As p_5, with account taken of gas solution and chemical reaction of oxygen.
p_2 = Internal gas pressure when transformer is cold after operation at full temperature; account being taken of gas solution.
p_1 = As p_2, but with chemical reaction of oxygen also considered.

sealed off from the atmosphere so that no breathing takes place.

Internal pressures occurring during operation cannot be calculated from the simple application of Charles's and Boyle's laws, and are shown to be affected by the process of gas solution in the oil. Solution of gas in oil follows Henry's law, and the volume of gas in solution is given by

$$v = kp$$

where v = Volume of gas (reduced to s.p.t.) in solution.
p = Absolute partial pressure of the gas, lb/in^2.
k = Constant derived from the Bunsen coefficient, and is taken as 0·00637 and 0·00565 for air and nitrogen respectively in transformer oil at 25°C.

Thus at atmospheric pressure saturated oil will have air in solution equal to about 9% of its volume.

If oxygen is present in the expansion space or in the oil it will react chemically with the oil, and its disappearance will reduce the internal pressures. Large negative gauge pressures can occur because gas which goes into solution during operation is not readily released when the transformer is cooled, even if the oil is saturated at the time of sealing. The greater the degree of unsaturation at sealing the greater is the negative gauge pressure. Conditions of filling and sealing therefore largely determine pressures during operation. The Figure on page 528 shows the variation of pressure in a sealed transformer.

It is known that pressure affects the electric strength of the oil. The degree of saturation with gas also has an influence. From limited data taken from the results of various authors, the variation of electric strength under conditions peculiar to sealed transformers is examined. Drops of the order of 30% are found possible. This occurs under conditions of large negative gauge pressure and with a degree of supersaturation of the oil with gas.

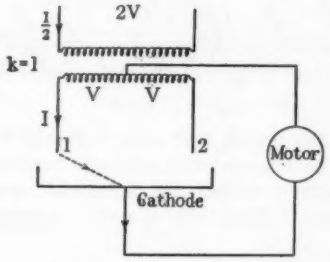
These findings based on limited data reveal the need for precautions and for further research.

A.C. Traction with Rectifiers

A DIGEST OF A PAPER (No. 1788) ENTITLED "SINGLE-PHASE 50 C/S A.C. TRACTION USING A RECTIFIER," BY A. MANDL, D.SC.TECH. THE FULL PAPER WAS PUBLISHED IN JUNE, 1955, IN PART A OF THE PROCEEDINGS.

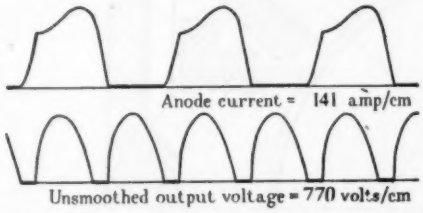
THE INCREASING USE of alternating current at industrial frequencies for electric traction has focused attention on the relative merits of two kinds of traction motors: the single-phase a.c. motor and the rectifier-d.c. motor. The design of single-phase motors for 50 c/s is fundamentally the same as that of the well-known 25 and 16⅔ c/s motors but the increased frequency aggravates the problems encountered. All experience gained on these equipments can be usefully employed for 50 c/s single-phase motors. The limitation in main-pole flux leads to a high-current motor with many brushes, and it is often necessary to regulate main-pole and compole fluxes carefully for starting and running to make the commutation comparable with that of d.c. motors. This requires additional equipment in the form of resistors, choke coils and condensers. The rectifier motor is free from this limitation and comes nearer to a d.c. motor. Additional equipment comprises a larger main transformer, rectifiers and smoothing equipment.

The scheme is shown in principle in Fig. 1 without the



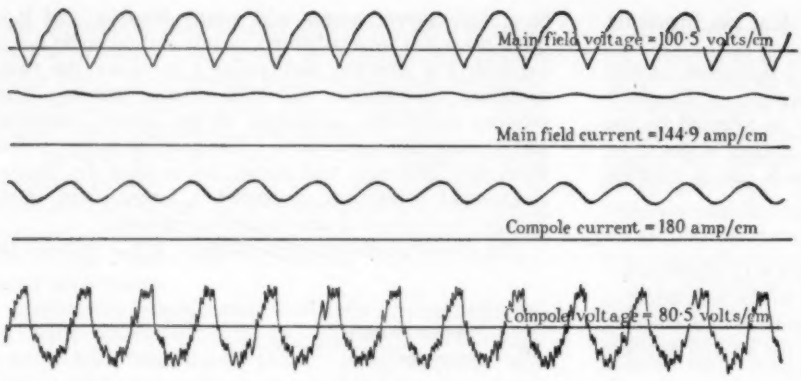
1 *Supply transformer—rectifier—traction-motor circuit*

necessary smoothing choke coil between cathode and motor. Fig. 2 is an oscillogram of rectifier output voltage and anode current. The output voltage is a commutated sine wave with small pieces cut out at the beginning of each half-wave during the time of overlap. It is an undulating voltage consisting of a useful d.c.



2 *Oscillogram of anode current and output voltage of rectifier*

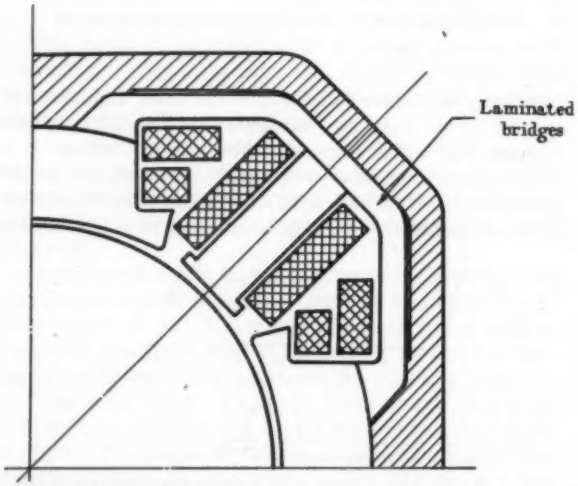
component and an alternating component in which the 100 c/s component with an amplitude of about 84% of the direct voltage is predominant. This voltage produces an alternating current which is limited by the total inductance of the d.c. circuit. A resistor in parallel with the main field winding diverts the ripple current and reduces the pulsation of the main flux to a small percentage. The large inductance of the main field winding is in this way virtually shorted out. The compole flux on the other hand should follow closely the undulating current. This can be achieved only if a laminated path is provided in parallel with the solid steel frame to carry the 100 c/s flux. The oscillogram shown in Fig. 3 has been taken on such a machine. Figs. 4 and 5 show the simple arrangement of a laminated path for a square and a round yoke. Without this laminated path the 100 c/s



3 *Oscillogram of main field voltage and current, and compole voltage and current*

Motor field shunted 15%. Two choke coils in series.

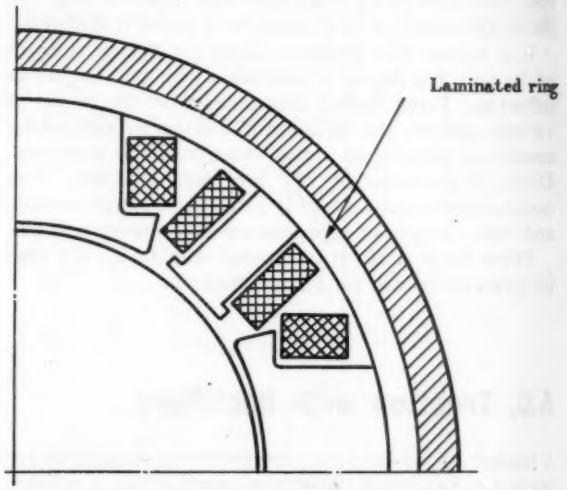
ripple of the compole flux is only half what it should be. The motor has then to be designed with reduced constants to keep the commutation within the sparkless zone since the compole field follows the armature current incompletely.



4 *Rectifier motor with square yoke and laminated bridges behind compoles and between laminated main poles*

Tests were carried out on two motors without and with laminated shunts parallel to the solid frame, and with different degrees of smoothing which resulted in ripple currents of 22%, 44% and 88%. The commutation was observed visually and on the cathode-ray oscillograph. The tests confirm that the commutation is considerably improved by laminating a small part of the yoke section. This makes it possible to use less smoothing equipment and to allow a greater ripple current. The ripple current increases the armature reaction and thereby the voltage between commutator bars, which is often a limiting design factor. The rating of the smoothing choke in volt-amperes is considerable, usually of the order of 50% of the motor rating. It is, however, wrong to prejudice the design of the motor by trying to obtain a high inductance of the armature circuit in order to save on smoothing equipment.

Distortion of the line current is an important problem; more smoothing of the d.c. output gives a squarer waveform of the line current, resulting in interference with adjacent communication circuits from the higher harmonics. Comparative tests have shown that all higher harmonics in the line current are reduced to about two-thirds of their previous values if the ripple current is increased from 22% to 44%. The value of the ripple



5 *Rectifier motor with round yoke and laminated yoke ring*

current will be a compromise between requirements of commutation and distortion of the line current.

The transient stability of the motor is adversely effected by the ohmic shunt to the main field winding. This is slightly mitigated by the additional inductance of the transformer and the smoothing circuit.

The rectifier motor which is connected to an undulating voltage works under different and more difficult conditions than an ordinary d.c. motor, and it can be understood that the design of the motor is affected in its most

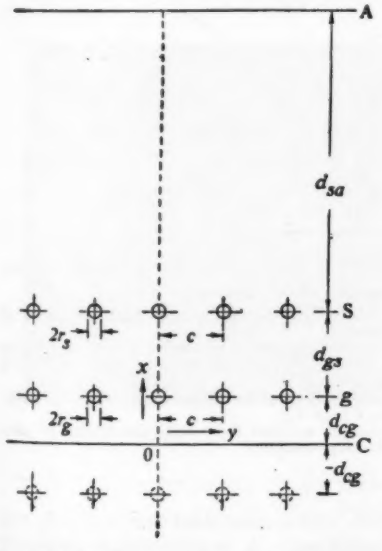
essential parts: commutation, commutator bar voltage, losses and transient behaviour, although special protection in the form of main-pole shunting and smoothing equipment has been provided. The normal d.c. traction motor can be used without any change only if it has sufficient margin in all essential points to cope with the 100 c/s current, or if a performance is accepted which would not be tolerated for the service on a direct voltage.

Beam-Valve Theory

A DIGEST OF A RADIO SECTION PAPER (No. 1835) ENTITLED "AMPLIFICATION CONSTANTS AND MUTUAL CHARACTERISTICS OF A BEAM POWER VALVE," BY S. DEB. THE FULL PAPER WAS PUBLISHED IN JULY, 1955, IN PART B OF THE PROCEEDINGS.

THE PAPER gives theoretical expressions for the amplification constants, and discusses a method for computing the mutual characteristics of a beam power valve when the distance between the control grid and the cathode becomes smaller than the control-grid pitch.

Rigorous expressions for amplification constants are obtained from direct analysis of the distribution of electrostatic field inside the valve. The analysis is carried out by extending the method given by Fremlin for a triode valve. Following Fremlin, the author derives the necessary potential function by taking into account the image of the control grid due to the cathode (Fig. 1). A consideration of the boundary conditions and of the electrostatic field in the vicinity of the cathode then gives:



1 *The transverse section of a beam power valve together with the image grid (shown dotted) due to the cathode*

C = Cathode. S = Screen grid.
g = Control grid. A = Anode.

μ_a (the amplification constant of the grid with respect to the anode)

$$= \frac{d_{cg}\left(\frac{2\pi}{c}d_{sa} - \log\frac{2\pi r_s}{c}\right) - \left(\frac{2\pi}{c}d_{sa}d_{cs} - d_{ca}\log\frac{2\pi r_s}{c}\right)\mathrm{f}(y, d_{cg})}{\frac{c}{2\pi}\log\frac{2\pi r_s}{c}\left(\frac{2\pi d_{cg}}{c} - \log\frac{2\pi r_g}{c}\right) - d_{cg}\log\frac{2\pi r_s}{c}\mathrm{f}(y, d_{cg})} \quad \ldots\ldots (1)$$

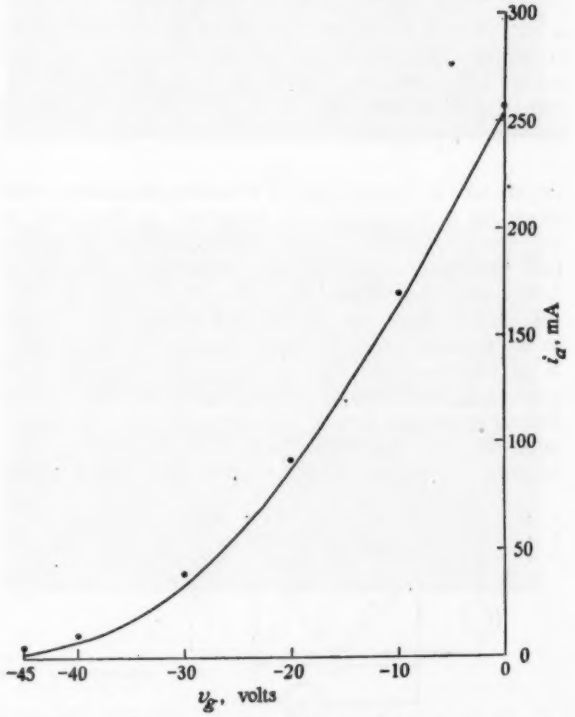
μ_s (the amplification constant of the grid with respect to the screen grid)

$$= \frac{d_{cg}\left(\frac{2\pi}{c}d_{sa} - \log\frac{2\pi r_s}{c}\right) - \left(\frac{2\pi}{c}d_{sa}d_{cs} - d_{ca}\log\frac{2\pi r_s}{c}\right)\mathrm{f}(y, d_{cg})}{\frac{2\pi}{c}d_{cg}d_{sa}\mathrm{f}(y, d_{cg}) - d_{sa}\left(\frac{2\pi d_{cg}}{c} - \log\frac{2\pi r_g}{c}\right)} \quad \ldots\ldots (2)$$

where $$\mathrm{f}(y, d_{cg}) = \frac{\sinh\frac{2\pi d_{cg}}{c}}{\left(\cosh\frac{2\pi d_{cg}}{c} - \cos\frac{2\pi r_g}{c}\right)} \quad \ldots (3)$$

and the symbols have the meanings indicated in Fig. 1.

Eqns. (1) and (2) show that, in general, both μ_a and μ_s will vary along the cathode surface—being a maximum for regions underneath the grid wires and a minimum for



2 *A mutual characteristic of a Type 807 beam power valve, illustrating agreement between the theoretically computed curve and experimental results*

V_a = 600 volts. V_s = 300 volts.
——— Theoretical curve. ••• Experimental points.

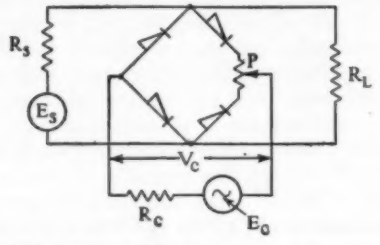
regions midway between these. These variations may also be interpreted as those of the various inter-electrode capacitance coefficients of the valve. If the average values of these capacitances are considered it becomes possible to define average values of μ_a and μ_s. These latter values are shown to be identical with the simpler expressions given earlier.

For computing the mutual characteristic of the valve the values of μ_a and μ_s, as given by eqns. (1) and (2), and the various electrode potentials are first utilized to convert the beam tube into an equivalent diode. The cathode-current density is then determined as a function of position relative to the grid wires and plotted graphically. The area bounded by the curve when multiplied by $(1 - 2r_s/c)$ gives the anode current. The mutual characteristic is obtained by repeating the above graphical operation for different values of the control-grid potential. The result of one such computation carried out for a Type 807 valve is shown by the solid line in Fig. 2 (page 531). The usefulness of the present analysis is illustrated by the close agreement between the theoretical curve and experimental results (shown as dots in Fig. 2).

Carrier-Leak in Shunt-Modulators

A DIGEST OF A RADIO SECTION PAPER (No. 1803) ENTITLED "CARRIER-LEAK IN RECTIFIER MODULATORS OF THE SHUNT TYPE," BY G. L. CONNON, B.SC.(ENG.), GRADUATE. THE FULL PAPER WAS PUBLISHED IN JULY, 1955, IN PART B OF THE PROCEEDINGS.

THE SHUNT (or Cowan) type of switching modulator, with which the paper is primarily concerned, is illustrated in its basic form in Fig. 1. Under the action of the carrier (or "switching") voltage V_c, the impedance of the rectifier bridge shunting the load R_L varies from a high to a low value according to the polarity of V_c. The signal output across R_L is therefore chopped at the carrier frequency f_c. With ideal rectifiers and a single-tone input signal at frequency f_s, this output comprises an infinite series of frequency components of the form $nf_c \pm f_s$, where n is odd. In this ideal case there is no component at a frequency f_c present in the output, the rectifier bridge

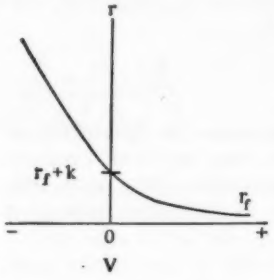


1 *Basic shunt modulator*

E_s = Signal source. R_L = Load.
E_c = Carrier source. P = Carrier-balance potentiometer.

being perfectly balanced. This is not, of course, achieved in a practical circuit, and the unbalance component arising from V_c is termed carrier-leak.

Rectifier modulators are most commonly used (in conjunction with filters) as frequency-changers, and many of them are required to handle an input of large dynamic range. The upper limit of input is set by overloading of the modulator, the lower limit, in many modulators,



2 *Typical diode a.c. resistance characteristic*

Represented closely by the equation:

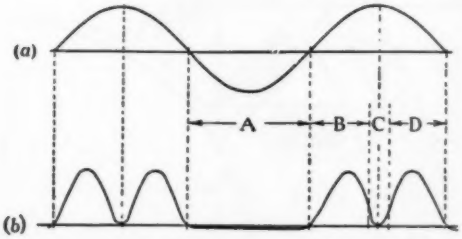
$$r = r_f + k\varepsilon - qV$$

(Logarithmic scale for r.)

by carrier-leak. It is therefore desirable to reduce the latter as much as possible.

With a square-wave carrier voltage in a non-reactive modulator circuit (or at low frequencies), conditions approximate to those of ideal switching, i.e. where the rectifiers switch instantaneously from a low constant forward resistance to a very high backward resistance. Carrier-leak is then quite calculable, and a very low total leak voltage (i.e. including all harmonics of the carrier frequency) is obtainable with a simple resistance balance such as the potentiometer P in Fig. 1.

A different situation exists however in practical, partly



3 *Form of carrier-leak voltage with sinusoidal carrier voltage*

Rectifiers conducting on positive half-cycles.

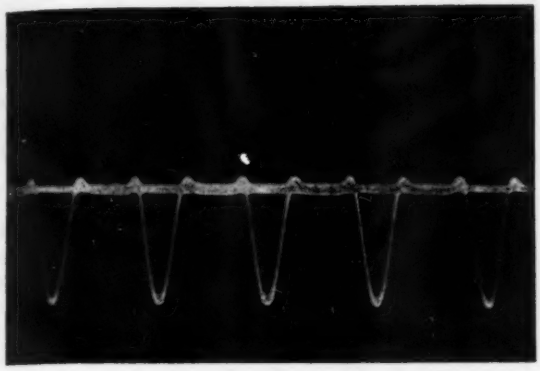
Period A: Leak voltage low owing to high back resistance of rectifiers.

Period B: High leak-voltage due to unbalance of rectifiers during transition from non-conducting to fully conducting condition.

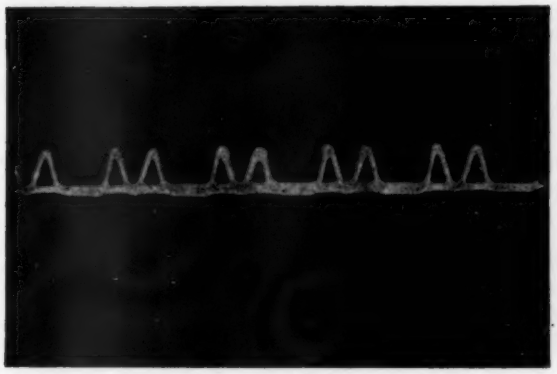
Period C: Leak voltage reduced by means of balancing potentiometer P (Fig. 1).

Period D: Transition of rectifiers from fully conducting to non-conducting condition.

reactive, modulators, with a sinusoidal carrier supply and thus imperfect switching. A mathematical approach to such modulators appears too formidable to be of much value, and therefore an experimental study was undertaken to investigate the causes of carrier-leak, and to



(a)



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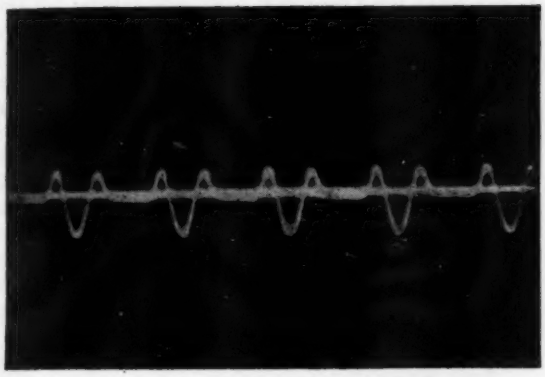

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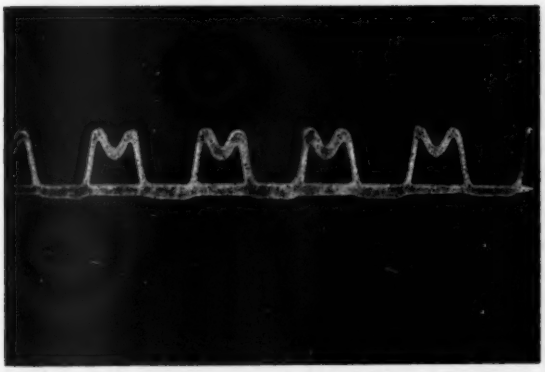

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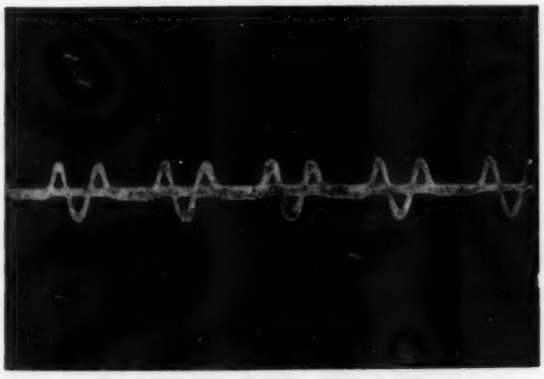

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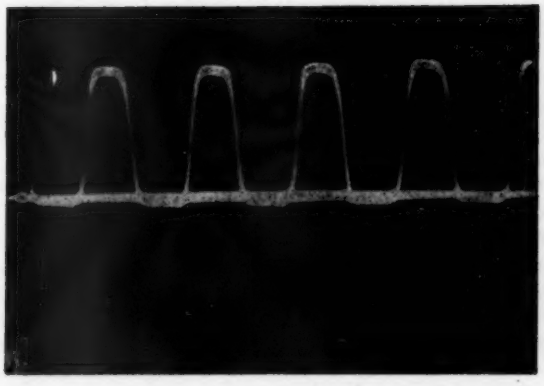


(f)

4 *Carrier-leak voltage waveforms illustrating effect of balancing potentiometer P*

$f_s = 3$ kc/s, $R_G = 500$ ohms, $R_L = 3{\cdot}3$ kilohms, and $V_G = 1$ volt forward peak.
Reference line at earth potential.
D.C. leak and r.m.s. fundamental a.c. leak voltages:

	μA	mV			μA	mV
(a)	−4	15		(d)	2	3·5
(b)	0	2·5 (d.c.-balanced)		(e)	4	10
(c)	0·8	0·2 (a.c.-balanced)		(f)	9	25

elucidate some of the factors affecting the attainment of very low leak levels (in the range 40–80 dB below the carrier voltage).

With a sinusoidal carrier supply, carrier-leak is caused chiefly by unbalance of the rectifiers during the transition period (i.e. as they change from forward to backward resistance and vice versa), and can therefore no longer be eliminated by a simple resistance balance. A typical form of rectifier characteristic is illustrated in Fig. 2, and an explanation of the generation of the characteristic carrier-leak waveform is given in Fig. 3. This is confirmed by results obtained in practice (see, for example, Fig. 4, which shows the effect on the waveform of the balancing potentiometer P).

Carrier-leak suppression obtained using a resistance balance with a sinusoidal carrier is thus inferior to that of the square-wave example quoted above, both as regards total leak (since the rectifier resistances are balanced over only part of the switching cycle), and also as regards suppression of a single frequency component. The latter is shown to be a result of unbalance of the circuit reactance, and it is demonstrated that by employing a reactive as well as a resistive balance control, suppression of fundamental carrier-leak (or of any single harmonic) of a very high order (greater than 100 dB) is possible on a short-term basis.

At higher frequencies (say above 50 kc/s), reactance unbalance plays a very large part in the production of carrier-leak. It is demonstrated that the minimum fundamental leak obtainable with resistive balancing alone rises linearly with frequency, and that a combination of resistive and reactive balance controls can be used to maintain a suppression of fundamental leak at least as good as that obtained by resistive balancing at low frequencies.

Another aspect of carrier-leak considered is the relation between d.c. and a.c. components of the leak. A note by Tucker* shows that with suitable design there may be close correlation between these components, permitting carrier-leak control and maintenance to be effected by a d.c. meter—a very desirable simplification. The analysis given was restricted to the case of a square-wave carrier in a non-reactive circuit. Experiments were therefore conducted to investigate the application of this method to practical modulators with imperfect switching. The results of these show that d.c./a.c. correlation, although inferior to that obtained with square waves, is still quite reasonable, even at high frequencies. It is concluded that the method is likely to prove very useful in practice, enabling fundamental leak voltages to be maintained at least 40 dB below the carrier voltage. A technique of accurate initial a.c. balancing followed by d.c. monitoring is suggested.

The effect of carrier generator resistance, the transformerless type of shunt modulator, and factors affecting the maintenance of very low leak levels, are also considered in the paper.

* TUCKER, D. G.: "Carrier-Leak Control in Rectifier Modulators by the Use of a D.C. Meter," *Proceedings I.E.E.*, Paper No. 1384 R (Part 2), November 1952 (99, Part III, p. 400).

Standard Waveguides

A DIGEST OF A RADIO SECTION PAPER (No. 1807) ENTITLED "STANDARD WAVEGUIDES AND COUPLINGS FOR MICROWAVE EQUIPMENT," BY A. F. HARVEY, D.PHIL., B.SC.(ENG.), MEMBER. THE FULL PAPER WAS PUBLISHED IN JULY, 1955, IN PART B OF THE PROCEEDINGS.

WAVEGUIDES ARE USED for equipment operated in the microwave part of the spectrum, which can be considered to extend from 60 cm to 1 mm wavelength (frequencies from 500 Mc/s to 300 Gc/s). The number of standard sizes of waveguide to cover adequately this spectrum depends on the bandwidth of propagation, while the dimensions should be directly proportional to their operating wavelength so that scaling of design is possible. Of the many possible types of waveguide, the rectangular section using the TE_{01} mode is in most general use and, in the first instance, it is only this type for which standard sizes are being proposed.

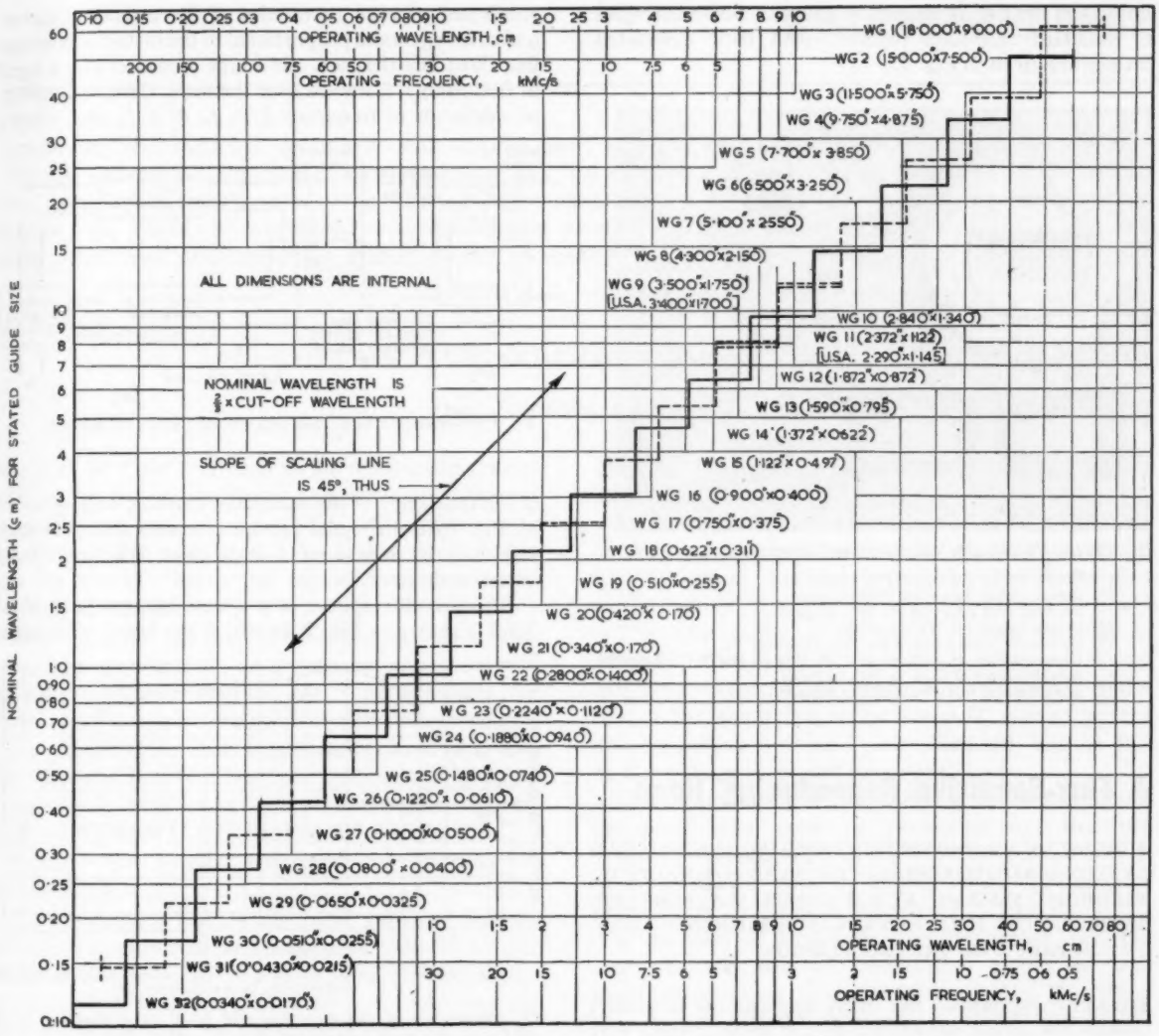
The optimum shape and size of waveguides must be chosen to give the required power-handling capacity at normal operating pressures before voltage breakdown occurs, while the phase velocity and impedance must not be unduly sensitive to operating frequency. Standard waveguides must be capable of accurate and economic manufacture in materials such as copper, brass, silver and aluminium. The complete series of waveguides covers internal dimensions from 0·034 in × 0·017 in to 18·000 in × 9·000 in, and their operating wavelengths are given in Fig. 1.

Waveguides require, for holding and alignment, couplings which consist basically of two flanges, the mating faces of which are flat, smooth and square with the waveguide axes. Other desirable requirements are that the flanges should be identical and symmetrical and there should be no possibility of incorrect orientation.

Reflections at a waveguide junction are caused by angular and/or lateral displacement as well as by differing cross-sectional dimensions of the mating waveguides. Since the voltage standing-wave ratio due to these causes should not be more than about 1·002 this accuracy of mating is difficult to achieve under practical conditions. Junctions less sensitive to small mechanical imperfections employ shims made of soft material or fitted with spring fingers. Choke systems can also be used, but careful mechanical and electrical design is required to produce a good broad-band performance with freedom from unwanted resonances.

To maintain correct internal pressure and to exclude dirt and moisture the flanges of the standard couplings are provided with grooves for sealing gaskets. The latter are of rubber or cork/rubber mixtures according to the particular design and are effective with differential pressures up to 50 lb/in over a range of temperatures from − 50° C to + 70° C.

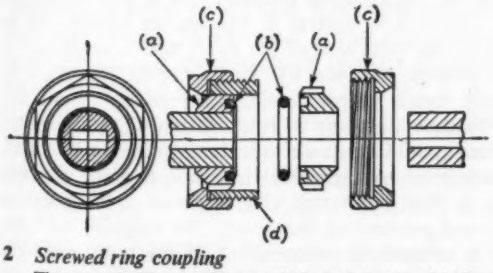
The coupling flanges are designed for medium-temperature brazing, although in lightly stressed components soft soldering is permissible. The attachment of



1 *Operating ranges of serial rectangular waveguides*

The waveguide dimensions shown are all internal. The nominal wavelength is two-thirds the cut-off wavelength.

aluminium guide and flanges is more difficult but several satisfactory processes are in current use.



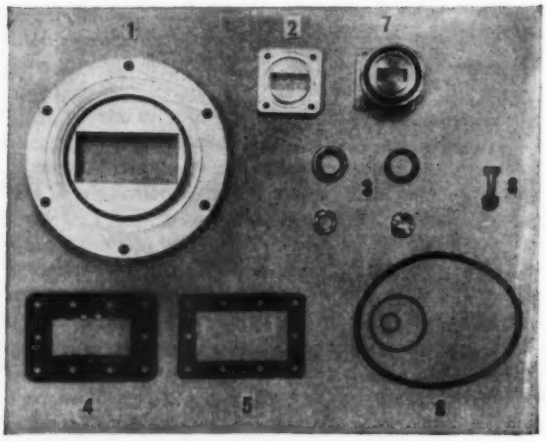
2 *Screwed ring coupling*

The example illustrated has plain lapped faces and is for use with WG 22 precision waveguide.
a) Plain flange. (*b*) Gasket. (*c*) Nut ring. (*d*) Locating ring.

A simple but satisfactory means of holding and aligning waveguide flanges is by close-tolerance bolts fitting into accurately bored and positioned holes. When the coupling has to be frequently disengaged a more convenient design is one in which lateral and angular alignment is provided by a keyed cylindrical sleeve, a typical example being shown in Fig. 2.

A range of adaptors is provided to facilitate mating of different waveguides and types of coupling, and these take the form of, and are fabricated in the same way as, simple waveguide components. The mechanical drawings of waveguide parts must contain not only such control information as hole spacings and sleeve diameters but specific parameters such as composition of the material, dimensional, flatness and squareness tolerances, surface

finish and the use of inspection gauges. Some examples of standard couplings together with their associated fittings are given in Fig. 3.



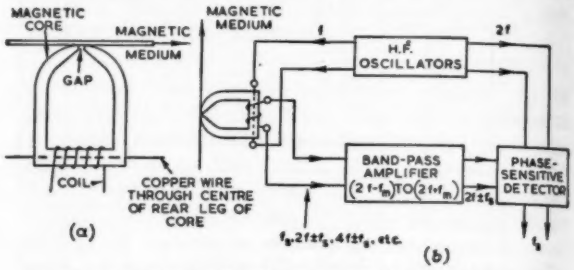
3 *Parts of waveguide couplings and adaptors*

(1) Bolted choke flange for WG 10 guide.
(2) Bolted choke flange for WG 15 guide.
(3) Screwed ring coupling for WG 22 guide.
(4) Contact shim for WG 11 guide.
(5) Flat cork–rubber gasket for WG 11 guide.
(6) Round rubber gaskets for WG 10, WG 16 and WG 22 guides.
(7) Adaptor from WG 15 to WG 16 guide.
(8) ¼in diameter fitted bolt and locking nut.

A Flux-Sensitive Reproducing Head

A DIGEST OF A RADIO SECTION PAPER (No. 1856) ENTITLED "A FLUX-SENSITIVE REPRODUCING HEAD FOR MAGNETIC RECORDING SYSTEMS," BY E. D. DANIEL, M.A., ASSOCIATE MEMBER. THE FULL PAPER WAS PUBLISHED IN JULY, 1955, IN PART B OF THE PROCEEDINGS.

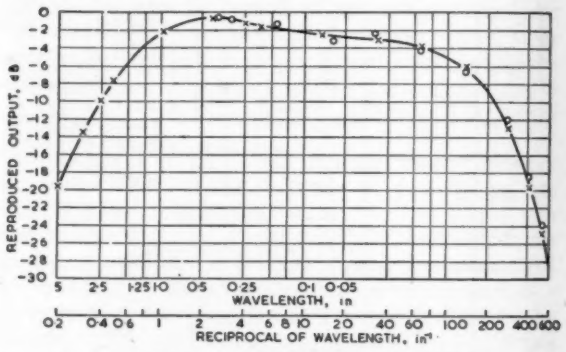
MAGNETIC RECORDING has many applications nowadays outside the sound-recording field and some of these may involve dealing with frequencies well below the audible range. Problems may arise in these special applications from the fact that the efficiency of a conventional magnetic recorder is proportional to frequency. A way round this difficulty is to redesign the reproducing head so that it responds to the instantaneous value, rather than to the rate of change, of the flux within its core. The paper describes one method of making a flux-sensitive head of this type. As shown in Fig. 1(*a*), the core of the head is conventional in shape but a conductor is passed through the leg on which the coil is wound. In operation, this conductor carries a high-frequency excitation current of sufficient strength to take a part of the surrounding core close to magnetic saturation. The system is a balanced one and no e.m.f. is produced in the coil until the magnetic characteristic of the core is disturbed by the polarizing effect of tape flux. When this occurs, an e.m.f. is produced having a frequency comprised of even harmonics of the excitation current and of a magnitude proportional to the instantaneous tape flux threading the core. If a tape recorded with a signal of frequency f_s is moved over the head, the e.m.f. consists of sidebands of frequency $2f \pm f_s$, $4f \pm f_s$, etc., where f



1 *Flux-sensitive head and associated electrical system*

is the frequency of the excitation current; and, as shown in Fig. 1(*b*), the signal can be extracted from the lower sideband by means of a band-pass filter and phase-sensitive detector.

The overall response of a system using a head of this kind is shown in Fig. 2, in which the lower scale can be



2 *Response of the experimental head as a function of the reciprocal of the recorded wavelength*

× Used as a flux-sensitive head.
○ Used as a conventional reproducing head and corrected by 6 dB/octave.

regarded as representing frequency at a tape speed of 1 in/s. The fall in output at frequencies below 1 c/s is caused by the finite size of the head, and is accentuated in the present instance by the fact that the head is unusually small (approximately ⅛in wide). Even so, with a moderate amount of equalization, the response of the system could be made substantially independent of frequency over an appreciable range. A point of some interest is that, although the response can never be entirely independent of frequency, the magnitude of the output is completely independent of the tape speed on reproduction; in fact the head will give an output from a stationary tape.

CORRESPONDENCE

LETTERS TO THE JOURNAL ON ELECTRICAL ENGINEERING SCIENCE OR TECHNOLOGY ARE WELCOME. IN PARTICULAR, MEMBERS (AND OTHER AUTHORS) WHO ARE SUBMITTING A PAPER TO THE INSTITUTION ARE ASKED TO CONSIDER THE POSSIBILITY OF MAKING A BRIEF PRELIMINARY ANNOUNCEMENT BY MEANS OF A LETTER BEFORE THE PAPER IS WRITTEN. CORRESPONDENCE SHOULD BE ADDRESSED TO THE SECRETARY OF THE INSTITUTION AND MARKED "FOR PUBLICATION." A CARBON COPY OF EACH LETTER SHOULD BE INCLUDED.

THE UNITS OF FLUX, FLUX-LINKAGE, PERMEANCE AND PERMEABILITY

From PROFESSOR E. BRADSHAW, M.B.E., M.Sc.Tech., Ph.D., *Member*

Mr. L. H. A. Carr, in a letter in the April *Journal*, drew attention to the unsatisfactory nomenclature at present in use for the unit of permeability. In agreeing with Mr. Carr on this basic issue, I should like to emphasize that the use of "henry per metre" is not so much "absurd," as incorrect.

After pointing out that various designations of this unit seem appropriate according to the particular relation in which μ appears, Mr. Carr advocates the omission of any unit designation after the expression "$\mu_0 = 4\pi \times 10^{-7}$." This is tantamount to saying that, because the unit of resistivity can be expressed as either "ohm-metre" or "volt/metre per ampere/metre^2," no designation should be used for the unit of resistance.

What is the correct designation of the unit of permeability?

The rationalized M.K.S. system of units is based on the metre, kilogramme and second as units of length, mass and time, respectively, and on a unit of permeability of such a size that the permeability of free space μ_0, expressed in this unit, has the value of $4\pi \times 10^{-7}$. The unit of permeability is therefore $(1/4\pi) \times 10^7$ times the permeability of free space. The unit of permeability is commonly stated to be the henry per metre, giving $\mu_0 = 4\pi \times 10^{-7}$ H/m. The purpose of this letter is to show that this nomenclature is open to objection. The objection is based on the fact that inductance, of which the unit is the henry, is a *circuit* parameter whilst permeability and the associated concept permeance are characteristics of a *medium*.*

In the course of the argument, it will be shown that (*a*) it is desirable that a name should be given to the M.K.S. rationalized unit of permeance; and (*b*) the volt-second is a unit of flux linkage and should be distinguished from the unit of flux, the weber, or volt-second per turn.

Consider a uniform magnetic circuit of length l, cross-sectional area A and permeability μ, which is wound with N turns. Let the current be I and the flux established Φ.

The inductance L of the *circuit* is given by $N\Phi/I$ or $V/(di/dt)$. The unit of inductance is therefore the Wb-T/A, volt-sec/A, or henry H (T ≡ "turn"). [The unit of flux, the weber, is the volt-sec/T, either from the above equation or from $V = -N(d\Phi/dt)$, and the unit of flux linkage is the volt-sec or Wb-T.]

The permeance Λ of the *path* is given by flux/m.m.f. or Φ/IN. The units of permeance are therefore Wb/A-T, volt-sec/A-T^2, or H/T^2. The permeability μ of the *medium* is given by B/H or $\Lambda l/A$. The units of permeability are H/m-T^2, Wb/m^2 per A-T/m, etc.

If the unit of permeance were designated, say, the *ewing* E, the unit of permeability would be correctly expressed in terms of E/m or H/m-T^2. Thus $\mu_0 = 4\pi \times 10^{-7}$ E/m. (Compare $\epsilon_0 = 8{\cdot}854 \times 10^{-12}$ F/m and conductivities in mhos per metre.)

Although "turns" may be thought to be dimensionless, it is the existence of turns which relates inductance to permeance ($L = \Lambda N^2$). The recognition of the importance of the turns is necessary to distinguish between L and Λ, and between flux linkage and flux. The somewhat similar function of the auxiliary dimension of "angle" in distinguishing between work and torque is relevant in this connection, i.e. work in joules, torque in joules per radian.

Apart from the question of the actual name chosen, I strongly urge that consideration should be given to a name for a unit of permeance. This would be preferable to a named unit of permeability; no names have in the past been given to units of permittivity and conductivity, and these units are correctly expressed as "farad per metre" and "mho per metre," respectively.

* BRADSHAW, E.: "Electrical Units" (Chapman and Hall), 1952.

Professor Bradshaw is Professor of Electrical Engineering in the Faculty of Technology, University of Manchester.

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A list of papers published in the August issue of Part A of the Proceedings appears under "Contents of the Current Issues of the Proceedings" on page 549, and the serial number of each paper and the month of publication of a digest in the Journal are included. Synopses of both monographs and papers which will be published separately before the next issue of the Journal appear below, and unless otherwise stated, their date of publication is the same as this issue of the Journal. The monographs will be republished in Part C of the Proceedings, and the relevant Part for the republication of a paper is given after the serial number of the paper.

MONOGRAPHS

A.C. Controlled Transductors

MONOGRAPH No. 141 M

A. G. MILNES, M.Sc., and T. S. LAW, B.Sc.

An analysis of the behaviour of the single-core auto-self-excited transductor element is made for the condition when the control circuit has finite resistance. Consideration is given to control by direct-voltage signal as an introduction to the performance with an alternating-voltage signal of the same frequency as the supply. Factors influencing the output characteristic are examined, and methods of improvement, such as phase shift and special bias arrangements, are discussed.

The a.c. control of full-wave transductors, and some push-pull circuits with half-wave and full-wave outputs, are referred to. The behaviour of a typical push-pull 4-element design is examined experimentally, and its performance when the control is by alternating-voltage signal is compared with that for direct-voltage control.

A digest of the monograph will be published in Part B of the *Proceedings*.

A Millimetre-Wave Magnetron

MONOGRAPH No. 142 R

J. R. M. VAUGHAN, B.A.

The construction and performance of a pulsed-millimetre-wave magnetron are described. The performance is compared with that of a "parent" valve, using Slater's scaling laws, and with theoretical standards. Some problems encountered in designing the valve and in holding close tolerances on the performance are discussed. The output coupling is analysed in some detail, including the effects of possible constructional errors. Test procedure is briefly described.

A digest of the monograph will be published in Part B of the *Proceedings*.

A Reflex Klystron Oscillator for the 8–9 mm Band

MONOGRAPH No. 143 R

D. J. WOOTTON, B.Sc., and A. F. PEARCE, Ph.D., F.Inst.P.

The paper describes a reflex klystron oscillator, tunable over the wavelength range of 8·9 mm, which is suitable both for use in a superheterodyne receiver and as a source for laboratory measurements. The cavity operates in its fundamental mode and tunes smoothly over the wavelength band. It is mounted in a metal envelope having a glass window through which the output power passes.

At an input of 2000 volts 10 mA, the output power of an average valve is about 30–50 mW, and the electronic tuning range to half-power is 60 Mc/s. Powers up to 160 mW have been obtained.

The factors affecting the performance of the valve are discussed, and consideration is given to the noise power generated by the oscillator when used in a superheterodyne receiver.

A digest of the monograph will be published in Part B of the *Proceedings*.

The Magnetic Screening Effect of Iron Tubes

MONOGRAPH No. 144

P. HAMMOND, M.A.

The magnetic screening effect of cylindrical iron tubes of different thicknesses and permeabilities is discussed, particular attention being paid to the effect of saturation. The problem is approached from a consideration of the induced polarity on the surface of the iron. It is shown that the variation of permeability around the tube produces space harmonics in the distribution of surface polarity, and that these harmonics cause a variation of the magnetic field from place to place in the region surrounded by the tube. Values of the theoretical screening ratio are calculated and good agreement is observed with values obtained experimentally.

A digest of the monograph will be published in Part B of the *Proceedings*.

The Calculation of the Equivalent Circuit of an Axially Unsymmetrical Waveguide Junction

MONOGRAPH No. 145 R

R. E. COLLIN, B.Sc., Ph.D., and J. BROWN, M.A., Ph.D.

The parameters of the equivalent circuit of an axially unsymmetrical waveguide junction may be calculated by a direct

application of the variational method developed by Schwinger. Certain useful properties of this method exist only when the junction has a certain degree of symmetry. A modification to the method by which these properties are retained even when the junction is unsymmetrical is developed and shown to be closely related to the Weissfloch method for the experimental determination of the equivalent circuit parameters. The method is illustrated by numerical calculations for the junction between an empty waveguide and one partially filled with dielectric: there is good agreement with experimental results.

A digest of the monograph will be published in Part B of the *Proceedings*.

Discrimination of a Synchronized Oscillator against Interfering Tones and Noise

MONOGRAPH No. 146 R

D. G. TUCKER, D.Sc., Ph.D., and G. G. JAMIESON

An account is given of the discrimination provided by a synchronized oscillator against unwanted signals accompanying the synchronizing tone; the synchronized oscillator is more specifically a non-linear regenerative tuned circuit. The discrimination is partly due to the frequency response of the system, but has also an important contribution from the non-linear behaviour of the circuit provided the wanted (synchronizing) signal has a greater amplitude than the unwanted (interfering) signals.

The monograph gives a general description of the phenomena of synchronization and non-linear discrimination, illustrated by experimental observations of frequency response and non-linear discrimination in resistance-capacitance-tuned oscillators. Both single-frequency and noise interferences are considered. It is concluded that very large amounts of discrimination can be obtained when the natural frequency of the oscillator is very close to the synchronizing frequency. The authors include a mathematical analysis of the effects, on the assumption that the non-linear law of the system considered has no terms above the cubic, and that the feedback loop has uniform amplitude and phase response over the frequency-band covered by the applied signals.

A digest of the monograph will be published in Part B of the *Proceedings*.

Microwave Propagation in Anisotropic Waveguides

MONOGRAPH No. 147 R

A. E. KARBOWIAK, Ph.D.

A detailed analysis of the propagation of electromagnetic waves in circular guides whose walls are anisotropic is carried out. The physical property of the wall is described in terms of "anisotropic surface impedance," and this has two principal components, which, in general, do not run along the co-ordinates of the cylinder. It is shown that, whatever the orientation of the principal axes of the surfaces, all E and H_0 modes are stable. Formulae are derived for the propagation and attenuation coefficients of the waves, and these are expressed in terms of the impedance components of the surface. Further, it is shown that all higher-order H modes are unstable in such guides unless the principal axes of the surface coincide with its co-ordinate axes.

A digest of the Monograph will be published in Part B of the *Proceedings*.

Junction Admittance between Waveguides of Arbitrary Cross-Sections

MONOGRAPH No. 148 R

E. D. FARMER, B.A.

A general formula for the admittance of the junction between two waveguides of arbitrary and different cross-sections, coupled end-to-end by an aperture of arbitrary shape, is derived by the application of Schwinger's variational procedure. It is shown that, if the dominant modes of either waveguide have similar patterns over the coupling aperture, the junction may be represented approximately by a 2-terminal network. A general and simple definition of characteristic impedance is introduced which enables one to regard the junction as an "impedance mismatch" together with a "junction effect" owing to short susceptance. The restrictions required for an exact 2-terminal description are discussed. The approximate 2-terminal theory is applied to the junction between two rectangular guides of different E-plane dimensions and the results obtained are compared with those derived elsewhere by a more rigorous method.

A digest of the monograph will be published in Part B of the *Proceedings*.

PAPERS

The Dynamic Braking of Induction Motors

PAPER No. 1885 U; Part A

D. HARRISON, M.Eng., Ph.D.

The paper gives a simple graphical method of predicting the dynamic braking torques, under all conditions, of slip-ring and squirrel-cage induction motors, taking full account of saturation and of the rotor leakage reactance. Test results confirm the accuracy of the method. It is shown that, in many motors, the rotor circuit reactance may be neglected, and the proper way of calculating the total deceleration time of an induction motor is given.

An On-Off Servo Mechanism with Predicted Change-over

PAPER No. 1895 M; PART B

J. F. COALES, M.A., O.B.E., and A. R. M. NOTON, B.Sc.

For a relay-controlled servo mechanism represented by an nth-order differential equation it is shown that one change-over, and one only, at a unique time, is necessary to bring error and error rate to zero in the least possible time. Previous workers have used the sign of a non-linear function to control change-over, but such methods are suitable only for simple second-order systems with step inputs. To satisfy the need of a technique capable of wider application, e.g. random inputs, prediction of switching by a high-speed repetitive analogue computer has been demonstrated with a model. Such a scheme has been shown to be practicable; its use is not limited to simple systems. In the specific example of a 10 kW control system the responses of the on-off control using predicted change-over are compared with those obtained (by simulation) of an orthodox servo mechanism—a linear but saturating servo. The optimized on-off control is always better for all amplitudes of step-, ramp- and parabolic-function inputs, and on the average the same performance would be obtained with both systems using only about half the torque with the on-off control.

SOME RECENT BOOKS

GERHART W. HEUMANN
MAGNETIC CONTROL OF INDUSTRIAL MOTORS

NEW YORK: JOHN WILEY. LONDON: CHAPMAN AND HALL. 2ND EDITION. 725 PP. £4 6s.

This is the second edition (revised and considerably enlarged) of a book first published in 1947 and already well known in control-gear circles as a useful reference work.

The fact that the author is himself a consulting engineer in the industrial control-gear department of a large manufacturing concern gives a practical bias to the book and added weight to the opinions expressed. Appreciating the control-gear engineer's need to have a thorough understanding of the operation of electric motors, the author wisely includes a comprehensive treatment of both a.c. and d.c. machines in the early chapters. This treatment is necessarily condensed but is adequate for an understanding of the circuits and problems discussed later.

To improve the value of the book as an aid to teaching, typical questions on day-to-day problems have been added as appendices to many chapters. Since organized courses on motor control as a separate subject are unusual in this country, the addition of solutions to the numerical problems would have enhanced their value to the individual reader studying alone. The formulae given in the early chapters would also be of greater value to students if more care had been taken to include the derivation of numerical constants.

To attempt to cover the whole subject of the control of electric motors in one volume, even of over 700 pages, is no mean task. The author has, however, countered brevity by an extensive bibliography at the end of each chapter.

Some of the chapter titles tend to be misleading and do not give adequate indication of the contents. In Chapter 2, for example, under the title "Principles of Direct Current Motor Operation," one finds a section on rotating amplifiers.

Although the author states that "because single-phase motors and a.c. commutator-type motors . . . are not frequently used in industrial applications at the present time, they are not treated in this book" some brief reference could have been made to their control. There is also a noticeable omission in the section dealing with single-phasing (page 133, *et. seq.*) where no reference is made to the current values and heating of a delta-connected motor under single-phase conditions.

Chapters 4 and 5 discuss d.c. and a.c. contactors and relays. More detail of contactor design and operating characteristics have been given than in the original edition, but from the students' viewpoint the treatment of a shading ring could have been profitably amplified by the inclusion of vector diagrams to illustrate its operation. Chapters 6 and 7 are concerned with accessories and pilot devices. In Chapter 6 a section on magnetic amplifiers has been introduced, but in about four pages only the briefest summary of their operation is possible. Although the reader is referred to other works on magnetic amplifiers more could with advantage have been written on their applications and operating characteristics. No comparison is made between the merits of rotating, electronic, and magnetic amplifiers with respect to such features as robustness, maintenance or response time, leaving the reader in some doubt as to their fields of application. The brevity of treatment of the magnetic amplifier is surprising in the light of a later chapter on electronic devices, where the author states his opinion that "electronic control will not supersede and eliminate magnetic control."

The chapters dealing with control circuits are profusely illustrated with clearly explained diagrams, and the various aspects of acceleration and braking are fully discussed. Probably because star-delta starting has not become common practice in America, no reference is made to it in this section although there is a brief comment in Chapter 2.

The book is well written and illustrated, and includes tables giving information about the performance of various components and machines, with numerous references to the standards of the National Electrical Manufacturers Association and the National Electrical Code of the United States.

F. OLLENDORFF
ELEKTRONIK DES EINZELELEKTRONS

VIENNA: SPRINGER-VERLAG. 655 PP. £8 5s.

In the introduction to his book on the electronics of the single electron Professor Ollendorff describes the motives which guided him in the choice of his material. He feels that the field of electronics is so vast that he must limit himself to electron or ion motion within electronic devices and cannot include all applications of these devices. He sets out to write a comprehensive treatise on the application, to the treatment of charged particles in electronic and ionic devices, of analytic mechanics, special relativity, geometrical optics, statistics and wave mechanics. He promises to write another volume on collective ion and electron problems including space-charge phenomena, which are excluded from the present book.

The treatise deals with single electron or ion motion in electric and magnetic fields. The author's book on potential fields is one of the standard works on the subject. The present book is much less self-contained. It presents applications to mass spectrographs, slit-anode magnetrons and cyclotrons which may serve as an introduction to the theory of such devices. The focusing properties of magnetic sector fields is omitted, which makes the treatment of mass spectrographs rather incomplete. The treatment of the cyclotron goes much further and includes a discussion of orbit stability.

The chapters on electron optics in relation to magnetic and electric lenses are the centre-piece of the work. The subject is opened with an introduction to Lagrangian and Hamiltonian methods. After a digression to spherically symmetrical magnetic fields and a discussion of Störmer's orbits and the polar aurora, the reader is introduced to Hamiltonian ray-optics. The geometry of collinear images is discussed in a general way before the image properties of electric and magnetic fields of cylindrical symmetry are analysed. Most of the important lens configurations are investigated in detail but periodic focusing and quadripole lenses are not included. The mathematical treatment makes full use of the devices of analysis. Here and elsewhere one is struck by the high mathematical standard which Professor Ollendorff can evidently expect from engineering students at the Technica

University of Haifa, Israel, where the book is offered as lecture material in the third year. The calculations throughout are carried out with reference to technological devices, and the developments are very detailed; elegance of presentation is sometimes sacrificed for didactic reasons (e.g. in the treatment of lens aberration). All this helps the reader to follow a rather difficult path. He is treated to a very clear exposition of the concept of the eiconal in its various aspects leading up to Seidel's and Glaser's developments. In the reviewer's opinion the subject of lens aberrations to which the higher theoretical developments lead is given too much weight in the plan of the book. It is a subject which is important to only a very small group of electron-microscope designers. Perhaps Professor Ollendorff judges that Hamiltonian methods should be taught because he expects important future applications; if that is so the space devoted to them might have been justified by including other material, such as some of Gabor's work on electron devices. The last part of the book is concerned with the theory of relativistic devices—betatrons, synchro-cyclotrons and synchrotrons. There is, however, no discussion of alternating gradient focusing, without which the subject of synchrotrons looks rather like Hamlet without the Prince.

It must be clear from the foregoing that the standard of the book is very high. Yet it bears the mark of a series of lecture notes edited as a book. It is not a reference book on any of the topics treated, except perhaps the non-relativistic electron optics of lenses. Neither is it a textbook suited to the curriculum of any of our university courses. Among electrical engineering students at English universities this book would be consulted only by research students specializing in electron optics. The highly detailed account of the dynamics of charged particles in fields does not lead up to the study of the essential features of the performance of electronic valves. Since space-charge phenomena are reserved for the second volume it is to be hoped that this will complete the picture to a large extent.

Some readers may feel that the work is rather remote from the technological applications which motivated Professor Ollendorff. But one realizes with him that a really comprehensive treatise would be a task of such gigantic proportions that it would probably be outdated before it was written.

H. COTTON (*Editor*)
ELECTRICAL EQUIPMENT IN MINES

NEWNES. 463 PP. £2 10s.

The book, which consists of a collection of specialized contributions by individual writers, is intended primarily for qualified engineers and students. Although informative and useful, some of the sections are unduly comprehensive. For example, twenty pages are devoted to compressed-air technique; seventeen pages are given to design and duty aspects of pumps; there are at least twenty pages of detailed calculations of haulage requirements; and twelve pages deal with calculations of the size and duty of motors and ropes in winding engines.

In the section dealing with power supply it is explained that the tendency to shut down all colliery generating stations and to take power from the C.E.A. has now been halted, and that it would be folly to put out of commission any further generating plant that may be available. The question of the efficiency of such generating stations must of course be considered, but the most important aspect is the provision of a supply of electricity in the event of failure of the supply from the C.E.A. In all-electric mines it is essential that power should be always available for the main surface ventilating fan to prevent the accumulation of firedamp at the coal face and in the roadways. Power must also be available for the electric winders in order that men can be raised to the surface from underground, and for the pumps to keep the mine dry or at least clear of flooding.

The statement on pages 58 and 59 of the section on switchgear, dealing with flameproof gate-end switchgear, that "interlocks are provided to prevent the isolator being moved to the ON position with the cover removed except by a responsible official with a special key . . ." is unfortunate. Mining regulations prohibit working on live conductors, and live metal which is not intrinsically safe should not be exposed. In a safety-lamp mine where, in addition to the risk of shock, there is serious risk of ignition of firedamp, published records show that accidents have occurred when electricians have put the mechanical interlock out of order.

Contrary to the statement in the section dealing with submersible pumps, it is unusual to fit a mining-type junction box at the pump motor. The usual box of this kind is not watertight and cable boxes of special design are called for. Three-core cables, unless of the wire-armoured type with the armouring securely attached to the apparatus at each end, may not comply with the mining regulations. Mine waters differ considerably in conducting properties and the metallic covering of the cable supplying the motor should itself have the necessary conductivity.

The Korndorfer auto-transformer starter may be employed for some of the large submersible pumps, but it is generally unnecessary for small sets and not essential as suggested by the authors.

The statement that a "submersible motor is to all intents and purposes a flameproof machine" is misleading, especially to a student. For information regarding flameproof enclosures the reader should study B.S. 229 and the Ministry of Fuel and Power Testing Memorandum No. 4, covering the construction and testing of flameproof apparatus.

The book, which is well illustrated, assumes that the reader has had a thorough training in the fundamentals of electrical engineering. The subject-matter is comprehensive, covering most of the electrical equipment associated with mines, such as power supplies, switchgear (including that used at or near the coal face), armoured and flexible cables for coal-face and other duties, coal-cutting machines, conveyors and drilling machines, operation on remote control, protection and safety features of electrical circuits. Electric winders, now steadily replacing steam winders, are dealt with. Useful information on underground lighting is given. Electrical signalling systems, an important part of mining electrical equipment, are also covered, and so are battery locomotives and trolley locomotives, of which the first installation in a British coal mine since the early part of the century is mentioned.

The book should be a useful reference volume for electrical engineers and others responsible for the installation and maintenance of equipment in mines. It is, apart from the illustrations, not very inviting to the eye, since, although the type is comfortably large, insufficient "leading" between the lines is used, and the margins are too narrow for the size of page used. Consequently pages that carry no illustrations appear rather black. In addition the binding is poor for a book of this quality and price.

LIBRARY ACCESSIONS

**Denotes that the publication is also in the Lending Library. The publications cannot be bought through The Institution; the publishers and the prices are given only for the convenience of members.*

BOOKS

AHRENDT, W. R. 621–52

Servomechanism Practice

Roy. 8vo. pp. 349. London: McGraw-Hill, 1955. £2 10s. *

This might well be considered a companion volume to "Engineering Cybernetics" by Tsien, for whilst the latter deals with the mathematical theory of the subject, which includes servo mechanisms, this book is a practical work dealing with circuits and components and giving actual values wherever possible.

AMERICAN RADIO RELAY LEAGUE 621.39(03)

The Radio Amateur's Handbook

32nd ed. Roy. 8vo. pp. 620 + 148. West Hartford, Conn.: A.R.R.L., 1955. $3.

AMERICAN RADIO RELAY LEAGUE 621.396.619

Single Sideband for the Radio Amateur

Roy. 8vo. pp. 176. West Hartford, Conn.: A.R.R.L., 1954. $1.50.

A collection of articles published originally in QST.

BAKER, C. 8.08

Technical Publications

Demy 8vo. pp. 302. London: Chapman and Hall, 1955. 36s. *

Discusses the different kinds of technical publications and suitable styles of writing for them. Deals with common grammatical errors, describes the collection of information, the use of illustrations—drawings, diagrams and photographs, the preparation of copy, and office and printers' reproduction methods.

BANNER, E. H. W. (Editor) 621.3

The Modern Electrical Engineer

5th ed. 4 vols. Cr. 4to. Vol. 1, pp. 334; Vol. 2, pp. 323; Vol. 3, pp. 417; Vol. 4, pp. 395. London: Caxton, 1955. £7 2s. 6d. (with The Modern Electrical Engineer Pocket Book).

An elementary introduction to the principles and practices of all branches of electrical engineering intended especially for those who must learn by themselves without the advantage of a teacher. All branches of the subject are dealt with in the four volumes, which contain, besides diagrams, many illustrations of the plant described.

BANNER, E. H. W.

The Modern Electrical Engineer Pocket Book

4¼ × 5¾ in. pp. 34. London: Caxton, 1955. (Issued with The Modern Electrical Engineer.)

Provides in a handy form wiring diagrams and tables of data useful for simple calculations on wiring, motors, etc.

BENTHAM, F. 628.973

Stage Lighting

2nd ed. Med. 8vo. pp. 362. London: Pitman, 1955. 37s. 6d.

A practical book dealing comprehensively with modern methods. Discusses apparatus, wiring and installations; stage lighting for various purposes; colour mixing and special effects.

BINNEY, E. A. 621.33

Electric Traction Engineering

Cr. 8vo. pp. 224. London: Cleaver-Hume Press, 1955. 15s. *

A review or introduction to the subject which describes the principles and methods involved in the choice and design of traction equipment. It outlines the development of the various systems employed and indicates likely future trends. The problems of machine design—including Diesel-generators, control arrangements, and problems of electrification, are explained.

BRECH, E. F. L. (Editor) 658

The Principles and Practice of Management

Demy 8vo. 752 pp. London: Longmans, 1953. £2 10s.

This comprehensive textbook covers in four sections the whole field of management. It explains what management is and what it does. The activities which come under distribution—sales organization, advertising, dispatch and transport—and production, including planning, control and supervision are described. The subjects of the other two sections are: personnel; and cost control and budgeting.

BROOK MOTORS LTD. 621.34

Alternating Current Electric Motors. Application and maintenance.

Cr. 8vo. pp. 274. Huddersfield: Brook Motors Ltd., 1954. 15s. *

Gives practical information and data on the speed and horse-power required of motors for various purposes, the installation of motors and control gear, causes and symptons of faults, power factor, etc.

HERDAN, G. 620.11

Quality Control by Statistical Methods

Cr. 8vo. pp. 251. London: Nelson, 1948. 21s. *

A concise explanation of the application of the mathematical laws of chance and probability to the sampling of manufactured products. The technique of using control charts and probability graphs is clearly explained in such a way that no mathematical ability on the part of the reader is necessary.

HEUMANN, G. W. 621.316.7

Magnetic Control of Industrial Motors

2nd ed. Roy. 8vo. pp. 725. New York: Wiley; London: Chapman and Hall, 1954. £4 6s.

Discusses the performance of motors, the characteristics of control devices, and the function of the commonly used control circuits including feedback systems. The book will be reviewed in a future issue.

LAJOY, M. H. 621–52

Industrial Automatic Controls

Demy 8vo. pp. 278. New York: Prentice-Hall, 1954. £2 13s. 6d.

An introduction to the principles of automatic control with descriptions of typical applications. Control system analysis is dealt with in the final chapter. Problems are given with each chapter for the reader to solve.

MOHR, O. (Editor) 621.316.7

Elektronische und magnetische Steuerungen und Regelungen in der Antriebstechnik. (Electronic and Magnetic Control and Regulation for Drives.)

Cr. 4to. pp. 124. Berlin: V.D.E.-Verlag, 1955. 14s. 7d.

ANNOUNCEMENTS TO MEMBERS

THE HOMES FUND

SUMMARY OF CONTRIBUTIONS RECEIVED TO 25TH JULY, 1955

	No. of Contributors	£	s.	d.
£1 000 and over	6	6000	0	0
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		£34917	16	8

PREMIUMS

The Council have made the following awards of premiums for papers during the 1954–55 Session:

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The Kelvin Premium (value £25)

H. I. Andrews, Ph.D., M.Sc. — "The Adhesion of Electric Locomotives"

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M. E. Haine, M.Sc., and M. W. Jervis, B.Sc.Tech. — "The Use of an Electron Velocity Analyser to stabilize a 50-kV Direct-Voltage source to a few parts in a million"

M. W. Jervis, B.Sc.Tech. — "A Precision Direct-Current Stabilizer"

J. C. West, Ph.D., B.Sc. — *For his part in a series of eight papers on the Theory of Non-Linear Servo Mechanisms, published during the last four years.*

Radio Section Premiums

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Letters of Commendation

W. D. Jackson, B.Sc.	"Computers and Computing Methods"	North-Western
R. W. Sutton, B.Sc.	"A Survey of Automatic Control Systems"	North Staffordshire
W. S. Tunnicliffe, B.Sc.(Eng.)	"An Introduction to the Transductor, with special reference to High-Speed Magnetic Amplifiers"	East Midland

COOPERS HILL WAR MEMORIAL PRIZE AND MEDAL

At their meeting on June 23rd, the Council awarded the Coopers Hill War Memorial Prize and Medal to Mr. D. McDonald, B.Sc., for his paper on "The Electrolytic Analogue in the Design of High-Voltage Power Transformers."

This prize, which was founded by the members of the Royal Indian Engineering College, Coopers Hill, in commemoration of members of the college who fell during the 1914–1918 War, is awarded annually by The Institution of Civil Engineers, and triennially in turn by The Institution, the School of Military Engineering, Chatham, and the School of Forestry, Oxford. The prize, which consists of a bronze medal, a certificate and about £20 in money, is awarded for the best paper on a professional subject published by The Institution during each 3-year period, and only authors who are Corporate Members under 35 years old are eligible.

APPOINTMENTS AND NOMINATIONS

OVERSEA REPRESENTATIVE OF THE COUNCIL FOR BRAZIL

Mr. C. H. de Nordwall, Member, has been appointed Oversea Representative of the Council for Brazil in place of Mr. T. Rees, M.A., Member. Mr. de Nordwall's address is Caixa Postal 3164, Rio de Janeiro, Brazil.

DEPUTY OVERSEA REPRESENTATIVE OF THE COUNCIL FOR INDIA

Mr. L. W. Brazel, Associate Member, has been appointed Deputy Oversea Representative of the Council for India. His address is c/o The Calcutta Electric Supply Corporation, Ltd., Calcutta, India.

DEPUTY OVERSEA REPRESENTATIVE OF THE COUNCIL FOR THE NEAR EAST

Professor R. W. Sloane, M.A., Ph.D., D.Sc., Member, has been appointed Deputy Oversea Representative of the Council for the Near East. His address is the American University of Beirut, Division of Engineering, Beirut, Lebanon.

BRITISH STANDARDS INSTITUTION TECHNICAL COMMITTEES:

Sub-Committee on Air-Break Switches and Breakers (ELE/10/2)

The Council have nominated Mr. H. W. Swann, O.B.E., Member, to serve as their representative on the above Sub-Committee and the newly appointed Panel which is to deal with miniature circuit-breakers.

Statistical Methods (Standardization and Specifications) (USM/3)

The Council have nominated Mr. S. Austen Stigant, Member, to serve as their representative on the above Committee in place of Sir W. Gordon Radley, C.B.E., Ph.D.(Eng.), Vice-President.

INTERNATIONAL CONFERENCE ON ELECTRONIC DIGITAL COMPUTERS

A conference on electronic digital computers and information processing, sponsored by the Gesellschaft für Angewandte Mathematik und Mechanik and the Nachrichtentechnische Gesellschaft im Verband Deutscher Elektrotechniker, will be held in Darmstadt, Germany, from the 25th to 27th October, 1955. Information about it may be obtained from Professor A. Walther, Institut für Praktische Mathematik, Technische Hochschule, Darmstadt, Germany.

RETIRED MEMBERS AND THOSE OF LONG STANDING

Members are reminded of a rule which has been in existence for some years and which enables Corporate Members and Associates who have retired from the profession and are still desirous of retaining their membership of The Institution to do so without payment of further subscriptions. It is left to the members concerned to make application to be brought within the rule. The rule, which does not apply retrospectively, is as follows:

Any Corporate Member or Associate who has reached the age of 60 and has retired from the practice of his profession or business may apply to the Council to waive his future annual subscriptions provided that his membership of The Institution has been continuous for at least 25 years. If he desires to continue to receive the *Journal* he can do so on payment of 10s. per annum. Parts A, B and C of the *Proceedings* will also be available to him at the appropriate subscription rates.

In addition to the foregoing, it should be noted that a further rule provides that as soon as a member of any class has completed 50 years of membership he will cease to be asked to pay any further membership subscriptions, regardless of whether he is still in remunerative employment. The rule operates automatically, and the member on qualifying is

notified accordingly. If he desires to receive the *Journal* or the *Proceedings* the arrangement for retired members of 25 years' standing also applies.

SIR GORDON RADLEY

A forthcoming appointment that will give much pleasure to many members is that of Sir W. Gordon Radley, C.B.E., Ph.D.(Eng.), Vice-President, as Director General of the Post Office. He will be the first professional engineer to have held this position. Sir Gordon, who is 57, joined the Post Office in 1920; he has been a Deputy Director General since last year and was Engineer-in-Chief from 1951 to 1954.

THE UTILIZATION OF ELECTRICITY IN SHIPS

A REVIEW OF PROGRESS

The August issue of the *Proceedings*, Part A, includes a Progress Review entitled "The Utilization of Electricity in Ships" by Mr. G. O. Watson, a Past-Chairman of the Utilization Section, who is Principal Electrical Engineer Surveyor of Lloyd's Register of Shipping.

The last Progress Review on this subject was published in the *Journal* in 1940, and the present review covers major trends and developments in the use of electricity at sea that have taken place since that date, excluding information on radiocommunication, radar and radio aids to navigation. As is customary in Progress Reviews, no technical development is described in detail.

The review consists of 15 sections under the following headings: Safety of Life at Sea; Rules and Regulations; Alternating Current; Generators; Slip Couplings; Electronics; Radio Interference; Cables; Fuses; Electric Propulsion; Refrigeration; Lighting; Galleys; Corrosion; and Miscellaneous. There are five photographic illustrations of marine electrical equipment, including an 850 kW closed-air-circuit generator with a heat exchanger, an electromagnetic slip coupling and some typical main-galley cooking equipment. Some of the interesting points considered by Mr. Watson in the review are: the International Conference on Safety of Life at Sea, 1948, whose International Code, which came into force in 1952, contains an innovation in the form of electrical provisions for such items as emergency lighting, ventilating fans and electric radiators with exposed elements; the question of alternating current versus direct current for ships' mains, with regard to which Mr. Watson states that the key problems are capital cost and the difficulty of producing an a.c. winch at an economic price; the increasing use of electronic equipment in ships and the problem of its maintenance; the fact that the United Kingdom still lags behind other countries in its use of rewireable instead of cartridge fuses in ships; the employment of electrical distance thermometers with refrigeration apparatus (such thermometers now being acceptable to Lloyd's Register of Shipping); cold-cathode fluorescent lighting; corrosion and the use of cathodic protection to mitigate it; and electrical harpooning.

SUMMER MEETING—PHOTOGRAPHS

The Hon. Secretary of the Scottish Centre, Mr. J. H. P. de Villiers, c/o Bruce Peebles and Co. Ltd., 19 Waterloo Street, Glasgow, C.2, will be grateful to hear from any member who has taken a 16-mm ciné-film of the Summer Meeting of The Institution. Mr. de Villiers would also like to borrow any interesting photographs of the meeting which members may possess; some photographs that have reached the Secretary of The Institution have already been lent to him.

BRITISH ASSOCIATION ANNUAL MEETING, 1955

The 117th Annual Meeting of the British Association will be held in Bristol from the 31st August to the 7th September, 1955. The President, Professor Sir Robert Robinson, O.M., F.R.S., will deliver his Address on "Science and the Scientist" at the Inaugural General Meeting in the Colston Hall on the evening of August 31st. The meetings of Section G (Engineering), which will be held in the University Engineering Building, include an address by the Section President, Dr. S. F. Dorey, F.R.S., on "The Influence of the Engineer on Sea Transport and Trade" (September 1st), and papers on transport (sea, rail, road, air and interplanetary) and on the engineering aspects of nuclear energy. As part of a full programme of social functions the Section G dinner will be held on September 5th.

Applications for membership should be made forthwith on the Association's registration form, obtainable from the British Association Office, Burlington House, Piccadilly, London, W.1. A detailed programme and an excursions guide will be sent to all those who have registered for the Meeting.

IRRADIATION IN INDUSTRY

THE U.K.A.E.A. FORMS A NEW GROUP

At a Press conference on June 14th, Dr. H. Seligman and Dr. R. Roberts announced the formation of the Technological Irradiation Group of the U.K. Atomic Energy Authority. This is aimed to promote the industrial use of "waste" fission products—notably caesium 137 and strontium 90—now becoming increasingly available from British reactors. Fuel rods withdrawn from a reactor are normally stored to allow radiation decay prior to processing for recovery of the original uranium and the plutonium produced in the reactor, and they can be used as radiation sources during this period. Residual liquors from the processing contain fission products which can be isolated and used as irradiation sources, caesium 137 being favoured for its convenience and long half-life of 33 years.

In a lucid exposition, and in answers to the many questions asked, Dr. Seligman and Dr. Roberts gave varied examples of the benefits industry was already getting, and could now expect, from irradiation techniques. Although much was made of the new methods of sterilization in medicine and of preserving perishable foodstuffs without refrigeration, several applications of interest to electrical engineers were given. For example, irradiation enables polyethylene to be made at far lower temperatures and pressures than now used, and considerably increases its heat resistance. Again, the irradiation of transistors has been found to have a stabilizing effect and to reduce the shut-down time, so enabling more rapid operation of circuits using them.

The new Group not only will be able to do all the types of industrial irradiation necessary, but will advise industry on the benefits and possible application of the new techniques. The U.K.A.E.A. hopes that industry will make much use of these facilities.

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